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G. HERBERT FOLLOWS, M. E., Associate Editor, CHARLES J. HAYES, Illustrator.

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HOME STUDY MAGAZINE.

Vol. III. FEBRUARY, 1898. No. 1.

HOME STUDY MAGAZINE FOR 1898.

IN THIS, the first number of the third volume of HOME STUDY MAGAZINE, we wish to heartily thank our readers for the many evidences of appreciation that have reached us during the past year. Not only has the number of subscribers largely increased, but we have received many letters commending, in unqualified terms, the simple manner in which subjects relating to theoretical and applied science have been treated.

In the later numbers of Volume II we deviated somewhat from the policy with which we started out, by giving up the grouping (in two-number editions) of articles referring to a particular trade or profession. Then we reserved a page or two for articles on "The Cooking of Wholesome Meals." These will be continued in the present volume, and will be followed by others of interest to the good housewife. Another new departure has been the introduction of articles on the most interesting events of the day, under the title of "Current Topics."

During the past year the space devoted to answers to inquiries has been doubled. This section of the magazine has proved unexpectedly popular, and our only regret is that it has been impossible to find room for answers to all the questions sent in.

In one respect this number differs from its predecessors. There is no separate drawing-plate or special section devoted to mechanical and architectural drawing. In future, these subjects, together with machine construction and design, will be dealt with in the body of the magazine.

The object of HOME STUDY MAGAZINE is the same now as it was two years ago, namely, to give to practical men that knowledge of mathematics, physics, mechanics, and drawing which they must have if their efforts to improve themselves are to be successful. The articles are written *by* practical men *for* practical men, and are of special value to those who are interested in mechanical engineering, steam engineering, civil engineering, electricity, plumbing, heating, ventilation, building, architecture, or allied industries.

It will be our earnest endeavor to present every subject in its true light and in the simplest language, to make the explanations concise, yet full, and to point out always the practical usefulness of the information conveyed.

Premium to Every Subscriber: On page III the reader will find full information regarding a premium to which every subscriber to HOME STUDY MAGAZINE is entitled. It consists of a complete course of instruction in practical Free-Hand Drawing and Lettering, under the direction of the International Correspondence Schools, of Scranton, Pa.

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NOTE.—For all information regarding HOME STUDY MAGAZINE see contents page.

THE STATICAL CONCEPTION OF FORCE.*

Antonio Llano.

ORIGIN OF THE IDEA OF FORCE—THE NATURE OF SCIENCE—STATICS THE ONLY POSSIBLE MECHANICS OF THE ANCIENTS—THE PASSAGE FROM STATICS TO DYNAMICS.

IF WE lift a heavy weight or press against a hard body, we experience a special sensation, or feeling, which we describe by a familiar name—*effort* (the same word serving also to denote our action upon the body). This sensation gives rise to a familiar idea—the idea of *resistance to motion.* We know from experience that we cannot move a body unless we exert a certain effort, however small. The change of a body from a condition of rest to one of motion thus becomes associated in our minds with the ideas of effort and resistance ; and when we see a body set in motion by the action of another, we imagine that the latter, in overcoming the resistance opposed by the former, exerts something like an effort, and is in a condition of strain similar to the strained condition of our muscles when we experience the sensation of effort. Nor is this all : when the effort we exert is not sufficient to overcome the resistance, we are none the less conscious of the fact that we are exerting an effort, or *tending* to move the body on which we are acting ; so that the sensation of effort always awakens the idea either of actual motion or of a tendency to motion. But we readily discern that our feeling is one thing, and our action, physically considered, is another thing ; and while we do not conclude that an inanimate body, when acting upon another so as to set it in motion, experiences a sensation, we do conclude that the action of the inanimate body, viewed in a purely physical light, must be the same as the action we exert to produce the same effect. This action of a body upon another, producing or tending to produce (or to prevent) motion, we call *force ;* and, although in this definition no mention is made of our sensations, the idea is implied that the action referred to is of that kind which, when exerted either by us or on us, is accompanied by the sensation of effort.

The preceding statements relate to the idea of force, as it naturally develops in our minds from our common experiences, before we are acquainted with the discoveries and theories of science. Experience is the source of all knowledge, and, as was remarked about twenty centuries ago by Aristotle, nothing comes to the mind except through the effects produced by the material world on our organs. We have, however, the faculty of grouping and combining the objects and the phenomena of nature with which we come in contact ; of referring them to one another, and of establishing relations between them. When we are able to refer a fact to another fact with which we are acquainted, we say that we have an explanation of the former fact and know something about it. Such is *science*, in the most general acceptance of the term : it is a knowledge of the relations between facts. This knowledge is never complete, and it is acquired at a comparatively slow rate. Before we discover the connections of the different facts we observe, those facts are by us described in terms of our sensations, as when we speak of colors or of taste. In this stage of our knowledge the sensation is of primary importance ; or, rather, it is the only thing we have to deal with, and the only standard of comparison. A consequence of this is the impossibility of conveying to others any adequate idea of the facts or phenomena that are known to us in this manner only ; for it is obvious that no one can explain colors to him who has never seen, nor music to him who has never heard. In order to obtain a truly scientific knowledge of phenomena, we must pass from the stage in which things are referred to the impressions they make on us, to the higher stage in which things are referred to their dependence on, or connection with, other things. Were we still in that primitive condition in which force

* It is hoped that every subscriber to HOME STUDY MAGAZINE will read this article carefully, as it is, in a manner, introductory to others on gravity, weight, mass, inertia, momentum, velocity, acceleration, work, energy, etc., subjects of which every engineer, whatever his specialty, should have a clear and full conception. The articles will be as simple yet as complete as possible and examples will be worked out to enable the reader to make practical use of the information conveyed.

is expressed in terms of our sensation of effort, we should have no science of force, no mechanics, as we have no science of taste or of smell. How the idea of force has become broader, and at the same time more definite, and how, by referring this property of matter to other properties of matter, instead of referring it to our feelings, force has risen to the level of an object of exact science, will be easily understood from what follows.

The sensation of heat is familiar to us all; yet we cannot measure heat by feeling, not only because feeling is not measurable, but because it is often misleading. If we immerse one hand in very hot water, and place the other on a piece of ice, and immediately afterwards put both hands in water at ordinary temperature, that hand will *feel cold* that was in the hot water, while the other will *feel warm*. Experience, however, has taught us that the property of matter which, under ordinary circumstances, produces *in us* the sensation of heat, produces *in other bodies* a peculiar change—expansion; and as this change is independent of our sensations, and capable of being accurately measured, we adopt it, not only as a means of comparison, but also as a definition of heat, or of temperature. We say, accordingly, that the temperature of a body is that state or condition on which, other conditions (such as pressure) being equal, the volume of the body depends. We choose a certain increase of volume of a certain body as our uni of temperature, construct an instrument to measure that expansion (a thermometer), and then—not before—we have a *science* of heat. Further investigations bring new facts to light, our conceptions are somewhat modified, our definitions are either extended or restricted, and our former standards are changed; but, whatever the changes introduced may be, comparatively little progress is made before the phenomena dealt with are expressed as *measurable* relations between external facts, that is, facts independent of ourselves.

With regard to the idea of force, several changes have taken place, and the science of mechanics has developed accordingly. The fact must have presented itself to the attention of man, at an early period of his history, that it requires some effort, not only to lift a body, but also to keep it from falling; for the moment the effort is relaxed the body falls quickly to the ground. This downward pull the ancients described as a "tendency of heavy bodies towards the center." We describe the same fact by saying that bodies are attracted by the earth; but, as we seem to know little more with respect to the real nature of the phenomenon than the ancients did, their description of the fact was perhaps as good as ours. At any rate, this "tendency" was found to produce the same feeling (the feeling of effort) as that produced by all other forms of resistance; whence the "tendency" in question was conceived and classified as force—not as *a* force, nor as a *kind* of force, but as force in general, there being, as we have already said, only one form of action called force; namely, the action of a body upon *another* by virtue of that property which, when the body acts on *us*, produces the sensation of effort. As this sensation is the specific characteristic by which force, wherever found, is distinguished from other properties of matter, it is naturally taken at first as the only standard of comparison, the same as the sensation of heat is at first the only standard for comparing temperatures. Before the thermometer was invented, the temperature of a body was ascertained by feeling it. So, too, in the early stage of mechanics, the weight of a body was ascertained by lifting or trying to lift it, the strength of a rope by pulling at it, the resistance of an obstacle by pressing on it. And since either weight, or resistance to compression, or resistance to tension, are all manifestations of the same fact—force, any one of them may be used to measure the others, if we know what the effect of force is, not indeed on *us*, but on *other bodies*. In this way we can reduce force to measurable relations among external facts, and then we may have a science of mechanics. But the science of mechanics did not spring up all at once; for, of the effects of force on bodies, only a vague and general idea was at first entertained; only some obvious facts were laid as the foundation of the science, and but one-half of the mighty structure was built by the ancients. They, of course, lacked that modesty so often preached, so seldom seen, in our time, and prided themselves on having left a finished work to their successors. Their successors, however, soon discovered that only half of the edifice was built; they laid the foundations for the other half, and soon "finished" the work. It is not improbable that *our* successors will have to "finish" the work again; nor is it by any means impossible that they may have to

begin the work anew, and reconstruct it from the very foundations, for it must be confessed that the fundamental principles underlying all our sciences are more or less hypothetic.

We have said that the science of mechanics begins when force is referred to and measured by its effects on external objects, that is, when it is defined in terms of external facts. What, then, is the physical effect of force? The ancients answered this question in a general way by saying that the effect of force is motion. We say "in a general way," because they were not concerned with the exact nature or amount of the motion produced; they conceived force as something that simply makes a body move, or disturbs the equilibrium of a body at rest. And here we have a further illustration of the origin of mechanical ideas; for the first thing with which experience makes us familiar is the moving of bodies by muscular effort; we do not pause to reflect on the velocity we impart to the body we lift, to the log we roll, to the peg we drive; all we are concerned with is the bare fact that we lift the body, roll the log, or drive the peg; it is nothing but breaking a state of equilibrium: beyond this the ordinary man of our day seldom goes, and the great mechanician of antiquity—Archimedes—never went.

The historical fact that mechanics began with statics is thus naturally explained. Statics is the science of equilibrium. In it force is conceived as either pressure or pull, and the motion caused by force is viewed as a disturbance of equilibrium, regardless of all other effects or circumstances. The mental process is simply this: it requires a certain muscular effort to disturb a certain state of equilibrium, and whatever disturbs that state of equilibrium is conceived as a force equivalent to the muscular effort, physically considered. Such being the case, the weight of bodies, regarded at first merely as their resistance to being lifted, at once suggests itself as a standard for measuring force. We have seen that the effort required to lift a body is (practically) the same as the effort required to keep it from falling; so that force, in its "tendency" to produce motion in one direction, may just prevent motion in the opposite direction. Here, then, we have the datum without which no exact comparison can be made—namely, *equality*. The "tendency of a body towards the center," that is, its *weight*, is a tendency to motion in a known direction, and any force that just prevents that motion we readily conceive as *equal* to the weight of the body.

The next thing is to devise an instrument, or apparatus, to measure weight, and a *unit* of weight that may serve as a standard to compare forces. For the measurement of weights, the simplest and oldest instruments are the pulley and the balance with equal arms. As for the unit, the weight of a piece of any material may be used. The piece is suspended from the arm of a balance, or at one end of a string passed around a pulley, and balanced by another body suspended from the other arm of the balance, or attached at the other end of the string passing over the pulley; then we have two units of weight. By balancing these two units we have four units, etc.

It may be worth repeating that weight is taken as a standard for the measurement of forces, not only because it produces in us the characteristic sensation by which all force is orignally known to us—the sensation of effort, but because it produces in other bodies the characteristic effect by which the physical nature of force is known to us—motion; and because any kind of action between bodies whose effect is motion may be replaced, in so far as this effect alone is concerned, by a weight. Or, taking the purely statical view of force, we may say that any state of equilibrium may be broken by the action of a weight, which is equivalent to saying that every force can be replaced by a weight. By the *magnitude* of a force is meant the weight that can replace it; so that, when we say a force is so many pounds or so many tons, we mean that a weight of so many pounds or so many tons will produce the same effect as the force.

Not having gone beyond the statical conception of force, Archimedes and his successors, up to the sixteenth century, left almost untouched the laws of motion, which in the mechanics of to-day play such an important part, not only on account of their theoretical value, but also, and perhaps more, on account of their practical value. This, however, by no means detracts from the greatness of the original investigators. They were treading almost virgin ground; they had no other teacher than nature, no other guide than their intellects, no other light than the light they themselves made; and they had to struggle with the traditions of an ignorant age, with their own inherited prejudices, and with the dogmatic errors promul-

gated in the majestic language of philosophy by such illustrious masters as Aristotle and Plato, the greatest of Greek thinkers. Archimedes is deservedly reputed the father of mechanics; he discovered the law of the lever, the laws of floating bodies and the properties of the center of gravity; while his mechanical contrivances were the wonder of his contemporaries, and still inspire us with admiration. The progress of man is a slow movement from the unknown to the known. We often, forgetting the origin of our knowledge, wonder at the ignorance of our predecessors, and can scarcely understand why they did not *see* facts and laws that seem to us self-evident. But this is a hasty judgment; there are no self-evident truths in nature. When we have become so familiar with a certain relation between facts that it is impossible for us to think of the relation being different from what it is, we say that the relation in question is a self-evident fact. History, however, teaches us that before this familiarity was acquired, many painful experiences, and often much profound thinking, were necessary; that many of the truths we regard to-day as axiomatic were brought to light by the prolonged study and the patient researches of the greatest intellects of our race; that mankind, like a child, began its journey along the route of progress with no knowledge whatsoever, and that knowledge, like all natural phenomena, is a process of evolution, whose effects, at first imperceptible, develop and multiply in something like geometrical progression. He who wonders at the ignorance of old times may be compared to him who wonders at the difference between the energy of a stone falling through a distance of one inch and an aerolite falling from the heavens: his very astonishment only serves to show that he has not yet become acquainted with the laws of nature.

At the present time our idea of force is perhaps as vague and indistinct as that of the ancients; but we have a clearer and more precise idea of its physical character, that is, of the external phenomena by which we define it. Motion, we have seen, is the external fact by which we know force; whence every motion, or, rather, every change of motion, is by us ascribed to the action of a force. Is there no relation between the nature of the motion produced and the magnitude of the force producing it? We readily see that when a force is applied to a body, not only the state of equilibrium of the body is disturbed, but the body passes to a state of motion, which can be clearly defined by measuring the space traveled by it in a certain time. The effect of a force on a body, then, is not only motion in general, but motion of a certain kind, measured by a certain velocity. Referring again to the example of heat, it will be remembered that when expansion was discovered to be the physical effect of temperature, the latter was measured by measuring the expansion produced. So, in the case of force, it seems natural that, once motion has been recognized as its distinctive effect, force should be measured by measuring the motion produced. This is the *dynamical* conception of force; it is the modern, and seems the most "natural" conception; yet it was many centuries before it was acquired; the science of motion is of comparatively recent origin. Here we are not concerned with the dynamical view of force; but we may remark, before closing this article, that the introduction of the new idea and of the new standard of measurement caused a complete revolution both in the world of science and in the world of industry. When there was no mechanics but statics, man might construct admirable structures—the pyramids of Egypt, the Roman aqueducts, or the noble edifices of Greece; and he might contrive some appliances for the transformation and transference of force, such as the war engines of antiquity. But the perfect machinery of to-day would be impossible if we knew nothing of the relations between force and motion—if we knew nothing of acceleration, momentum, work, energy, and other dynamical factors that enter as indispensable elements into the proper design of almost all modern mechanisms.

THE GAS-ENGINE.

E. W. Roberts.

Two-Cycle Engines—The Clerk Engine—Vertical Engines—A Valveless Engine—A Simple Mixing-Valve—Gas Versus Electric Light.

PART III.

NO SOONER had the Otto engine been placed upon the market than a host of inventors set to work to devise improvements, or, in some cases, simple modifications, in order to avoid conflicts with the Otto patents. One of the chief objections to the Otto cycle is that the engine employing it must be built four times as strong as a double-acting steam-engine of the same horsepower and running at the same speed, for the Otto engine gives but one power-impulse to the steam-engine's four. This circumstance led to the invention of the two-cycle engine, in which there is one impulse in every revolution. The first engine of this type (invented by Mr. Dugald Clerk), was put upon the market in 1880. Although it is no longer manufactured, it can truly be said to be the parent of the two-cycle type, and, as with the early Otto engine, a description of the Clerk engine is necessary before proceeding with the more modern types.

In Fig. 1 is shown a vertical section of the engine-cylinder along a line passing through the center. Fig. 2 is a similar horizontal section. Besides the principal or motor-cylinder *A*, the engine has an auxiliary cylinder *B*, with a piston *D*, Fig. 2.

The auxiliary piston *D* is attached by a separate crank to the fly-wheel of the engine, and this crank is so set that it reaches the end of its stroke just ahead of the motor-piston *C*. *I* is a slide-valve similar to that employed on the earlier Otto engine, but is used for the purpose of ignition only. This valve is operated by a bell-crank lever *b* attached to the spindle *g*, which is given a reciprocating motion by means of an eccentric on the crank-shaft. *F* and *H*, Fig. 1, are poppet-valves, both of which open upwards when subjected to the suction within the cylinders. Surrounding the lower valve *H* is a gas-channel *K* from which gas enters the space above the valve through a number of small holes in the valve-seat. At *Q* are "quieting" pistons, so designed that the valve is checked by an air-cushion when returning to its seat. This device does away with the disagreeable rattle which is so frequent an accompaniment to a poppet-valve engine. The water-jacket *J* surrounds the cylinder *A* and the compression-space *C*, as shown in the figures. No water-jacket is necessary for the auxiliary cylinder *B*, no gases being burned in it.

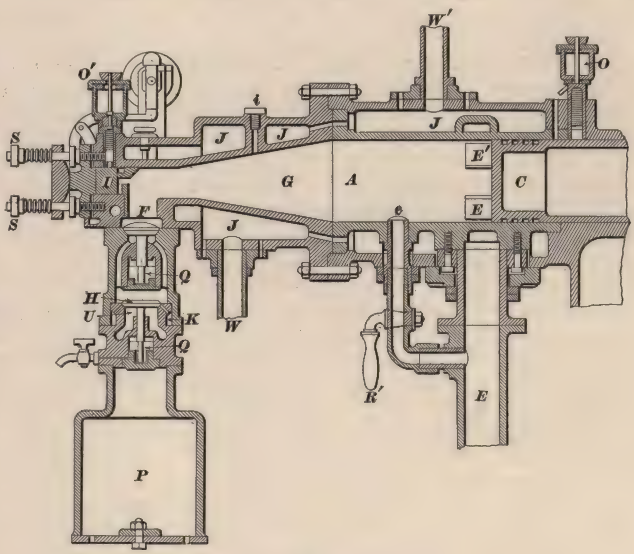


Fig. 1.

The following series of operations takes place in this engine: The auxiliary cylinder, or pump, first draws in a charge of air

through the valve *H*, which, as it enters, carries with it the required proportion of gas from the channel *K*. On the return of piston *D* the mixture is forced through valve *F* into the motor-cylinder *A*. Valve *F* opens just as piston *C* has passed the edge of the exhaust-ports *E*, *E′* and the pressure in the motor-cylinder has dropped below that in the pump. The ratio of the volumes of the two cylinders is so adjusted that the fresh mixture drives the greater part of the exhaust gases from the cylinder *A*, and yet no unburned gas escapes through the exhaust-ports. The piston *C* covers the exhaust-ports on its return, both cylinders compressing the charge until piston *D* starts on its forward stroke. Just as this occurs, the rush of gas from *A* into *B* closes valve *F*, and the compression is completed by the piston *C*. Ignition takes place immediately on the completion of the compression-stroke and the expanding gases drive the piston forward until they escape through the exhaust-ports.

The above is readily seen to be a clever modification of the Otto cycle, the pump doing the work of the suction-stroke and of the exhaust-stroke and aiding in compression. The pump is connected by the passage *W* with the space between the valves *F* and *H*. *L* is a gas-valve under the control of the governor; from it the gas flows to the gas-channel *K*. The valve *L* is so arranged that it closes just before piston *D* reaches the end of its stroke, so that the final portion of the charge is pure air. This is, of course, the first portion of the charge to enter the motor-cylinder, and the chances of fresh gas escaping through the exhaust-ports are reduced to a minimum.

The action of the ignition-slide will be fully explained in the next article on gas-engines. Owing to the greater frequency of the explosions in this engine, the Otto valve was not suitable. At *R′*, Fig. 1, is a relief-cock which is opened when starting the engine. It allows the gases to escape from the cylinder until the compression-stroke is half completed, in the same manner as the starting-cam on the Otto engine.

There are quite a number of engines on the market to-day using what is, practically, Clerk's modification of the Otto cycle. In the Robson engine the front end of the cylinder is enclosed, the piston having a rod with gland and stuffing-box, as in a steam-engine. The fresh charge is drawn into, and compressed in, the front end of the

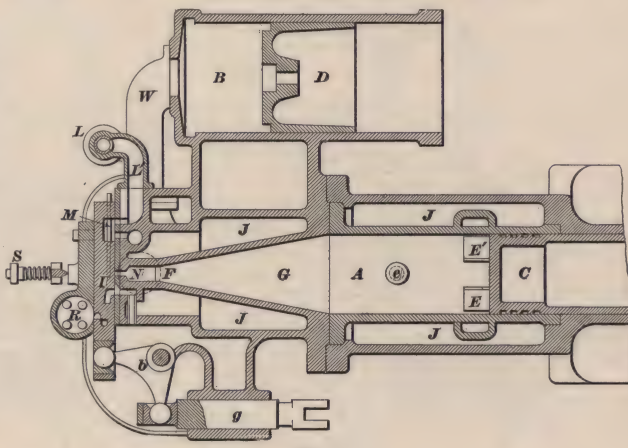


Fig. 2.

cylinder much in the same manner as in the pump-cylinder of the Clerk engine. From the front end the charge is forced into a receiver at a pressure of about 5 pounds per square inch. As soon as the pressure within the motor-cylinder falls below that in the receiver, a new charge enters and drives the burned gases out through the exhaust-ports. The next, or return, stroke of the piston compresses the charge and draws a fresh mixture into the front end of the cylinder, which it discharges into the receiver during the expansion-stroke. This engine, as the reader will see, is quite similar in operation to the Clerk.

An ingenious engine, and one of which great things were expected, made its appearance in 1886. It is known as the Atkinson cycle engine and has, in addition to the ordinary valve mechanism, a link-motion so designed that the piston makes two long and two short strokes during each revolution of the crank-shaft. The charge is drawn into the cylinder by a short stroke beginning at the extreme back end of the cylinder. The gases are then compressed by a still shorter stroke, and, after ignition, expanded by a long stroke to greater volume than the mixture possessed at the end of the suction-stroke. The piston then returns until it reaches the *end* of the cylinder and all the exhaust gases are expelled. Theoretically, this engine produced an ideal cycle, but the

great difficulty lay in the maintenance of the link-motion. The engine never became a pronounced commercial success, and it was finally withdrawn from the market.

neared the end of the stroke a small piston-valve, operated through stem b' by the eccentric c, opens communication to a hot tube t, and the charge is ignited.

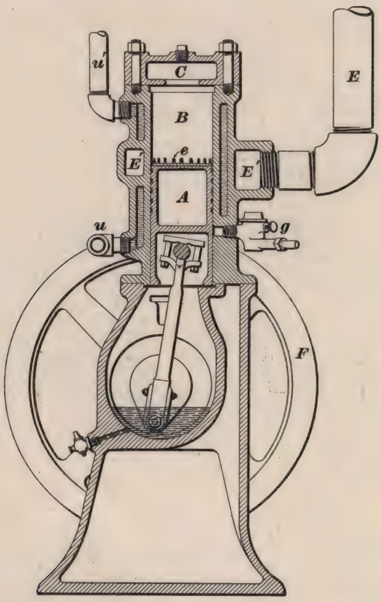


FIG. 3.

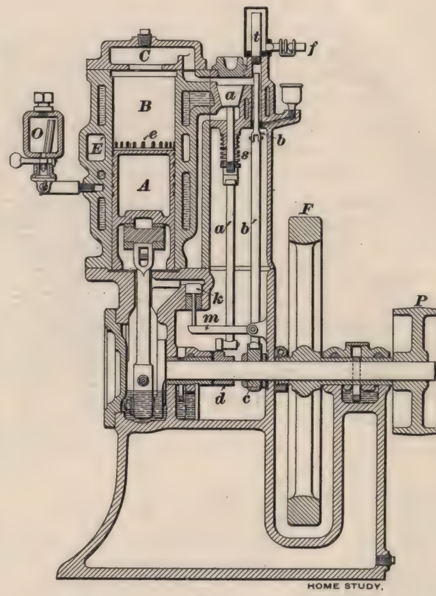


FIG. 4.

In Figs. 3 and 4 we have two sectional views of the Nash engine, a well-known modern representative of the two-cycle type. It is similar to the Robson engine in that it uses the end of the cylinder towards the crank for a charging-pump. But instead of using a piston rod and stuffing-box, this engine has its connecting rod and crank enclosed in an air-tight crank-chamber. Upon the upstroke of the piston a charge of gas and air is drawn into the crank-chamber. The succeeding downward stroke compresses the contents of the chamber, while a former charge is being expanded in the upper part of the cylinder. At the end of the stroke the exhaust gases escape through the exhaust-port e to the annular space E', and thence to the atmosphere through the pipe E. While the gases are escaping, the valve a is opened by means of the cam d operating through the valve-stem a' and a small roller on the end of a', the valve being held to its seat during the remainder of the cycle by means of the spring s. On a being opened, the fresh mixture drives the exhaust-gases ahead of it, and the cylinder is completely filled with the new charge. Compression now takes place, and when the piston has

At k a small governing-valve, attached to the governor by the lever m, controls the passage of the compressed charge from the crank-chamber to the working-end of the cylinder. The amount of charge entering the upper end of the cylinder is thus regulated according to the load on the engine, and an impulse of varying strength is given to the piston at each revolution, unless the load becomes so small that the valve k is entirely closed. A very steady-running engine is produced by the use of such a device, and an engine so governed is well adapted for driving electrical machinery, although its efficiency on light loads is decreased.

The heavy fly-wheel F stores up energy for compressing the charges and running the machinery during the intervals between the power impulses. The machinery is driven from a pulley P by means of a belt. Gas enters the crank-chamber through the valve g, the air-inlet and mixing-valve not appearing in the figures. Water enters the jacket at u and passes out at u'. The manner of lubricating this style of engine is shown in Fig. 4. At the bottom of the chamber is a layer of water which reaches up far enough

for the crank to dip in it at the lower end of the stroke. Oil floats on top of the water and is dashed over the reciprocating parts of the engine at each revolution, ensuring perfect lubrication. At *O* is an oil-cup for lubricating the piston, the surplus oil from which flows to the crank-chamber below. The ignition-tube is heated by means of the burner *f*. These engines are built in various sizes from ½ to 200 horsepower, sizes above 10 horsepower being supplied with from two to four cylinders.

Gas-engines are so often placed in care of persons unskilled in handling machinery that it has been the aim of many designers to produce an engine with the fewest possible number of parts. There is no better example of what can be done in this line than the original Day engine, an illustration of which appears in Fig. 5. Strictly speaking, this engine consists of but four essential parts. They are the cylinder and the frame (one piece), the crank-axle and its attached pulleys and fly-wheel (one piece), the connecting-rod, and the piston.

The operation of the engine is as follows: On the upstroke of the piston a partial vacuum is produced in the crank-chamber *e*, and when the piston uncovers the port *h* a charge of gas and air enters the crank-chamber, the air from the pipe *n* and the gas from a governor-valve; this valve is not shown in the figure. On the return of the piston the mixed gas and air is compressed to about 4 or 5 pounds above the pressure of the atmosphere. Near the end of the stroke the piston passes the exhaust-port *g*, and, immediately afterwards, the port *f*, communicating with the crank-chamber, is opened, and the entering charge, striking against the deflecting-plate *i*, passes to the top of the cylinder and down again in the direction of the arrows, driving the exhaust gases ahead of it and practically clearing the cylinder of the waste material. On the return of the piston the charge is compressed as usual, and is fired at the proper moment by a hot ignition-tube inside the chimney *l*. The method of timing the ignition will be explained in a later article. It will be noticed that air is drawn into the crank-chamber from the base *k*, which it enters through the small holes to be seen at the right. This arrangement is for the purpose of quieting the air-current, since it enters the crank-chamber with a rush.

The production of a vacuum in the crank-chamber meant a useless expenditure of energy, and the engine was afterwards so modified that the air entered the chamber through a check-valve, the air and the gas being drawn in during the entire upward stroke.

An engine having a cycle in all respects similar to the Day is manufactured by the Sintz Gas-Engine Company. A side and an end elevation of the Sintz engine are shown in Fig. 6. The engine uses gas or gasoline with equal facility, and, as shown in the figure, the special features necessary when employing gasoline as a fuel are retained.

The piston carries a deflecting-plate, and the admission- and the exhaust-valves are arranged as in the Day engine, a poppet-valve check controlling the admission of the charge to the crank-chamber. This valve, which is of unique design, is shown in detail in Fig. 7. The connections for gas are shown in dotted lines, Fig. 6. The gas from the meter passes through the rubber gas-bag *g*, the valve *g′*, and the pipe *g″* to the mixing-chamber *M*, Fig. 7. The gas-bag acts as a regulator to equalize the flow of the gas into the mixing-chamber. Air enters the holes *h*, Fig. 6, and flows over the top of the cylinder through the brass cylinder-head casing *n*, downward through the pipes *Y* to the mixing-chamber *M*. By passing over the cylinder-head the air is heated, so that when using gasoline the oil is vaporized in the mixing-chamber by contact with the warm air. The valve *V*, Fig. 7, is raised by the suction of the piston during the filling of the crank-chamber and is closed by the spring *S* when the pressure in the chamber falls. When gasoline is used it is fed to the mixing-valve by means of the pipe *r* from a tank placed above the level of the engine. The gasoline flows first to the reservoir *R*, which regulates the flow of the oil. From the reservoir the liquid flows to the compartment *Z*, Fig. 7, from which it is

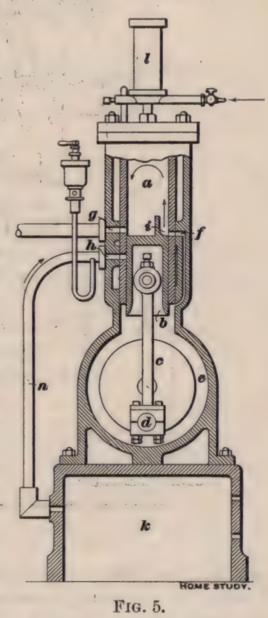


FIG. 5.

admitted to Z' by the needle-valve v', the opening of which is shown on a graduated circle A by the stationary pointer p.

The mixing-valve itself will be seen to have two seats; the larger valve-face V controls the mixture, while the lower face v opens Z', allowing gasoline to flow into the mixing-chamber M. The warm air from both sides of the mixing-chamber passes over the surface of the liquid, changing it into gas and carrying it, thoroughly mixed with the air, into the crank-chamber. The charge passes from the mixing-valve in the direction of the arrows past the butterfly-valve x, which is operated by the short crank a outside of the pipe. By opening and closing this valve the quantity of the mixture entering the engine may be increased or decreased. The crank a is jacket and is expelled at w'. E is the exhaust-pipe. The fly-wheels f have broad faces, so that either one of them may be used as a belt-pulley. The force-feed oiler o supplies a lubricant to the piston and the crank-chamber. The priming-cup c is used for charging the cylinder with gasoline after the engine has been standing idle long enough to get cold.

This engine is manufactured in twelve sizes, from 1 to 30 horsepower. Sizes from 4 horsepower up are built with two cylinders. The makers claim that the two-cylinder engine is a very satisfactory source of power for electrical purposes.

The latest adopted method of dynamo-driving marks a bold step in gas-engine practice, and speaks well for the improvements that have been made in gas-engine

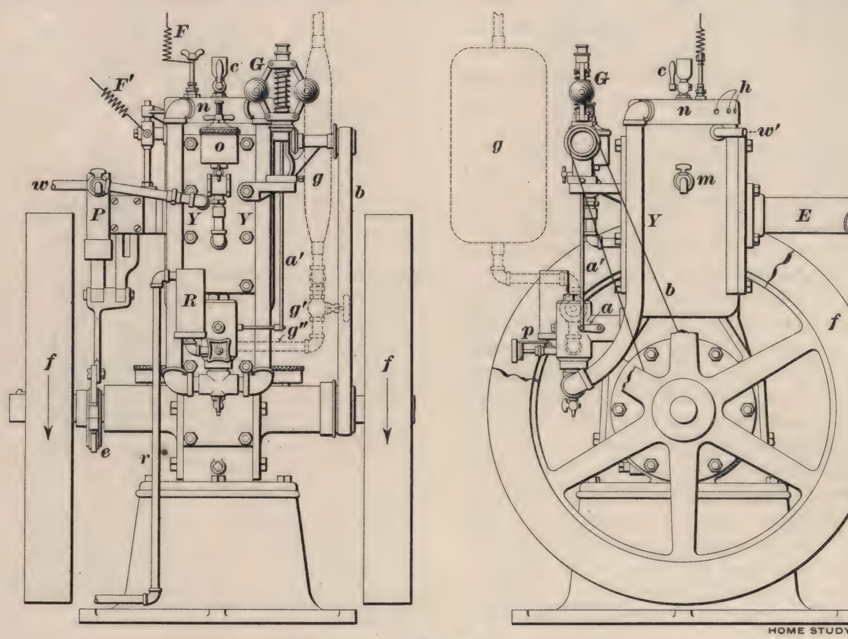


FIG. 6.

attached to the governor G by the rod a'. Thus, the regulating mechanism is similar to that in use on the Nash engine. The governor is driven from the crank-shaft by the belt b.

The charge is ignited by electricity. The ends of the igniter-wires may be seen at $F F'$. This igniter will be fully described in Part IV of this series. Both the igniter and the water-pump P are driven from the same eccentric e. Water enters the pump at w, whence it passes through the water-speed-regulation. The engine and dynamo are bolted to the same frame. The engine is of the four-cycle type, but has two cylinders so arranged as to give an impulse for every revolution of the crank-shaft. The dynamo-shaft is connected to the crank-shaft of the engine by means of a flexible coupling, which is provided with four long helical springs, through which the entire power of the engine is transmitted.

Any small irregularity of motion is taken up by the springs, and does not affect

the dynamo. The governor regulates the amount of the charge, so that the engine receives an impulse every revolution, whether running heavy or light.

If, instead of burning gas in an ordinary jet and obtaining light in this way, we use the gas to drive a gas-engine and dynamo, much more light will be obtained. Figures present a more forcible illustration than a mere statement of this fact, as the following example will show. It is customary to assume that each engine-horsepower will furnish sufficient current for ten 16-candle-power incandescent lamps, or one 800-candle-power arc-lamp. If the gas we are to use is 20-candle-power gas, the consumption per horsepower delivered to the dynamo will not exceed 18 cubic feet for average working; 20-candle-power gas gives 20 candle-power for each 5 cubic feet of gas burned in one hour in the ordinary fishtail burner; so 18 cubic feet would give $\frac{18}{5} \times 20 = 72$ candle-power. Thus, we gain an increase in illuminating power of 1.22 per cent. by using a gas-engine and a dynamo in conjunction with the incandescent light. In the case of the arc-light, however, the increase is enormously greater, more than eleven times as much light being obtained from the same amount of gas. It might be as well to state in conclusion that these figures are by no means exaggerated, much better results being frequently obtained in practice.

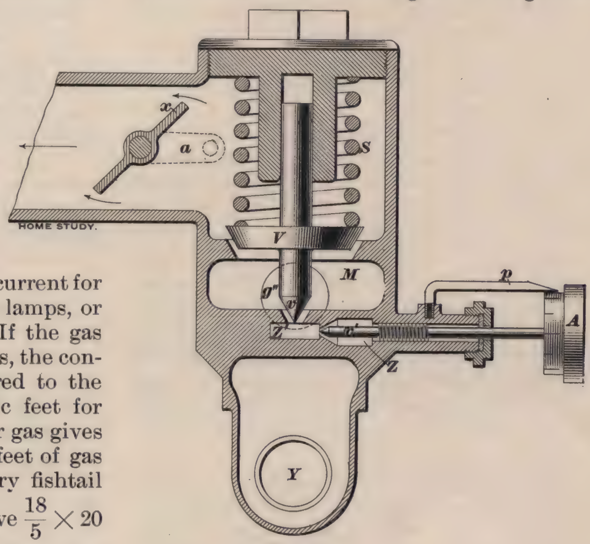


FIG. 7.

GALVANOMETERS, AMMETERS, AND VOLTMETERS.

Herman A. Strauss, E. E.

FUNDAMENTAL LAWS OF THE ELECTRIC CIRCUIT—THEORY OF ELECTRICAL MEASUREMENTS. ELECTRICAL MEASURING INSTRUMENTS—COMMERCIAL MEASUREMENTS—CALIBRATION.

THE ELECTRICAL CIRCUIT.—That which interests us mainly in any electrical circuit is the strength of the current flowing therein and the value of the pressure causing that flow. By virtue of the pressure the current is not only caused to flow, but it is also enabled to overcome a certain obstruction which may be placed in its path, such as that constituted by what is called *electrical resistance.* The quantity of this electrical resistance which any current can overcome is, however, limited by the current pressure; that is to say, if a given pressure will force a certain current through a known resistance, then, if the pressure is reduced by one-half, it will no longer be able to force the same current through the same resistance. Experiment has proved that, with half the pressure, either one of two conditions is possible. These conditions are:

1. One-half the pressure will force the same current through one-half the resistance.

2. One-half the pressure will force one-half the current through the same resistance.

The relation is equivalent to saying that *the pressure is proportional to the current and to the resistance.* When any quantity is

proportional to two other quantities, it is equal to the product of the two quantities; so that if

E = electrical pressure, or electromotive force;
C = electrical current;
R = electrical resistance,

we may write,

$$E = C \times R; \quad (1)$$

from which formula we obtain, by transposing,

$$C = \frac{E}{R}, \quad (2)$$

and

$$R = \frac{E}{C}. \quad (3)$$

These three formulas (which will be referred to later by their numbers) give us, in terms of the other two, the value of any one of the three electrical quantities of a circuit. The relation expressed by the formulas was first discovered by Dr. G. S. Ohm, of Berlin, Germany, and is known as *Ohm's law.*

In this article we will confine our attention to direct-, or continuous-current circuits, for which Ohm's law holds *absolutely.*

Measurements.—All measurements of resistance, pressure, and current strength are based on Ohm's law.

The electrical engineer, in the practice of his profession, often finds it necessary to make numerous and daily measurements of this kind. To facilitate this work, instruments have been devised which can be quickly connected to any circuit, and which at once indicate, by means of a pointer moving across a scale, the exact value of the quantity to be measured in that circuit. These instruments indicate the conditions of the electrical circuit in a manner similar to that in which the steam gauge of a boiler indicates the condition of the steam circuit.

Current.—The *strength* of an electrical current is, in practice, measured by a unit which has been named the *ampere*, in honor of the French scientist, *Ampere.* Any instrument, therefore, which will measure the strength of the current in amperes, is called an *ampere-meter* (that is, a meter, or measure, of amperes). This word ampere-meter is often shortened to *ammeter.* In electrical manufacturing establishments particularly, and in practice generally, the latter designation is almost exclusively used.

Pressure.—The pressure, or electromotive force, of an electrical current is, in practice, measured by a unit which has been named the *volt*, in honor of the Italian scientist, *Volta.* Any instrument, therefore, which measures the pressure of an electric current in volts, is called a *voltmeter* (that is, a meter, or measure, of volts).

Resistance.—The resistance of any substance to the passage of an electric current is, in practice, measured by a unit which has been named the *ohm*, after the already-mentioned German scientist of that name. Instruments designed to measure ohms directly, have been constructed and are in extensive use in laboratories, or wherever exceedingly accurate measurements are absolutely essential. Two instruments of this kind are the *Wheatstone bridge* and the *ohmmeter.*

The practical electrician, however, rarely makes use of them. Measurements which are correct within one-fifth of one per cent. are near enough for him and are considered exceedingly good, and as there are both ammeters and voltmeters on the market, which give results approaching or even better than this, the practical engineer contents himself with *indirectly* determining the electrical resistance of any circuit by the use of formula (3).

According to this formula, the resistance is given by the quotient obtained, when the pressure of the circuit is divided by the strength of the current flowing therein. The method of procedure is, then, to measure the *voltage* of the circuit with a voltmeter, and the *amperage* with an ammeter. A simple calculation is then all that is necessary, namely:

$$\frac{\text{Volts}}{\text{Amperes}} = \text{Ohms}.$$

The use of the two instruments, the voltmeter and the ammeter, is, as a rule, all that the practical engineer requires for the various measurements of the electrical circuit.

Theory of Construction.—The most practical, efficient, and (within the limits stated above) the most accurate instruments in general use to-day, as ammeters and voltmeters, are those which rely for their action upon the effect which a closed coil, carrying a current, has upon a magnet; or—vice versa—upon the effect which a magnet has upon a closed coil, carrying a current.

A fundamental experiment illustrating this effect is shown by Fig. 1, in which a magnetic needle NS, is suspended on a pointed pivot which allows it to turn easily. Above the needle and parallel to it is a conductor carrying an electric current, the current flowing in the direction indicated by the arrow. Immediately this conductor is

brought into the position shown, the needle turns briskly aside, the N pole of the needle turning toward the east. If the conductor is moved, and held *below* the needle, the N pole of the needle at once turns in the

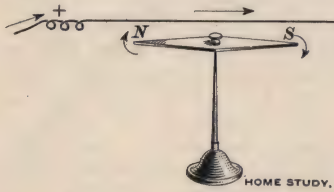


FIG. 1.

opposite direction, toward the west. These movements can be firmly fixed in the mind by the following rule, originated by Ampere:

To determine the direction toward which a magnetic needle will point when influenced by an electric current, imagine yourself swimming in the conductor, with the current; turn your body so as to face the needle, then the N pole of the needle will turn toward your left hand.

In other words, the deflection of the N pole of a magnetic needle, as viewed from the conductor, is *always* toward the left of the current.

Now it must be remembered that the magnetic needle, when not influenced by an electrical current, will point north and south, because of the directive forces of the earth's magnetism. Therefore, when a conductor, as above shown, is brought near the needle, the electric current in the conductor must overcome this tendency of the needle, and therefore the final position which the needle takes is a resultant of two forces, namely, the earth's magnetism and the current in the conductor. If the latter

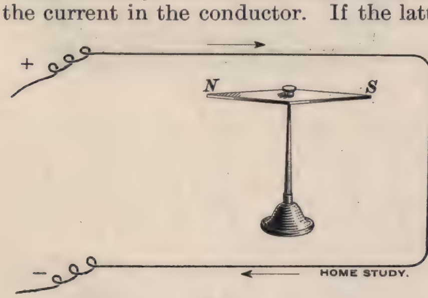


FIG. 2.

is very strong, the needle will turn widely around, approaching a direction at right angles to its original position, whereas, if the current is weak, the needle will turn very little. To exert a greater effect upon the needle, we may arrange the conductor as shown in Fig. 2.

In this arrangement the same conductor is simply carried back *beneath* the needle, and hence both the upper and the lower conductor influence it. The side branch has no effect upon the needle. In accordance with Ampere's swimming rule the *upper* conductor causes the N pole of the needle to turn to the left. Now, if we apply the rule to the *lower* conductor, that is, if we imagine ourselves swimming in the lower conductor in the direction of the current, and facing the needle (that is, if we swim on our back), the N pole of the needle will turn to our left, which is exactly the same effect the upper conductor has upon the needle; and we thus see that the turning forces exerted by the current upon the needle will be the same for both upper and lower conductors; in other words, the effect of the complete loop of wire, as in Fig. 2, is double the effect of one single conductor.

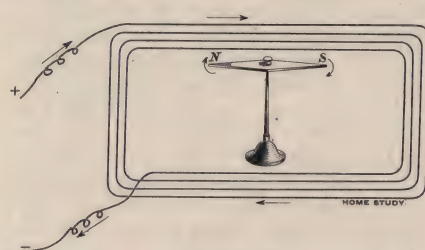


FIG. 3.

Experiment further shows that the effect upon the needle grows with the number of such complete loops, so that the arrangement shown in Fig. 3, which consists of a coil of wire of many complete turns, will powerfully influence the needle.

Since the distance through which the needle of Fig. 3 will turn depends upon the strength of current flowing in the coil, this arrangement forms a very simple indicator of current strength. Thus, suppose the N pole of the needle turns 2 inches to the left, when a current of a given strength is flowing in the coil; then we know in all future work, with that instrument, that whenever the N pole of the needle turns 2 inches to the left, a current having that once-for-all determined value is flowing in the coil. An instrument of this kind is called a *galvanoscope*. When it is accurately constructed, and supplied with a scale showing how many degrees the needle turns when a given current flows in the coil, the instrument becomes an actual measure, or *meter*, of currents, and is then called a *galvanometer*. The needles of galvanometers

are usually supplied with a spring or similar attachment which brings the needle back to its original, or zero, position whenever the current in the coil dies out. To make these instruments more sensitive in responding to the influence of a current in the coil, they are often fitted with an attachment whereby the effect of the earth's magnetism on the needle is annulled, thus leaving it subject to the influence of the coil alone. This attachment very often consists of a permanent bar magnet, which is placed in the plane of the coil and parallel to it, and which exerts about the same effect on the needle as the earth's magnetism does, but in the opposite direction, the two forces about neutralizing each other.

Calibration for Amperes.—It is possible to *calibrate* a galvanometer, that is, to ascertain, by special measurements or comparison with a standard instrument, the number of amperes corresponding to any particular deflection of the needle or pointer. Thus, suppose it has been positively determined that a deflection of the needle of 180 degrees is produced by a current of 5 amperes flowing in the coil; then a current of 5 amperes will *always* produce that deflection if the instrument remains in the same condition. When, by a series of such comparisons, the various equivalent currents for certain deflections have been ascertained, the galvanometer scale may be divided up into amperes, so that the strength of the current, in amperes, may be read directly from the instrument. Such a galvanometer should be called an *amperemeter*. A device of this kind would, however, be too delicate—too sensitive—for practical work. The commercial ammeter, while embodying principles similar to those just stated, is constructed in a different manner.

Commercial Ammeters. — An instrument specially constructed for practical work, and in extended use in this country, is shown by Fig. 4.

In this instrument, the conductor which carries a current does not act upon a magnetic needle, but upon a metal core built of many strands of iron wire closely bound together, as shown at C. The coil itself, A, into which the current is carried by way of the contact a, and which it leaves by way of the contact b, is in the form of a hollow coil, called a *solenoid*, in which is the core C suspended from the hook h on the cross-arm P. This cross-arm is supported on a knife-edge bearing, and the weight of the core C is balanced by the counterweight W to such an extent that the needle N points to zero on the dial D.

The action of the instrument is as follows: The weight W at one end of the cross-arm P tends to keep the pointer N at zero. When the current comes on and traverses the solenoid, the core is "sucked" down into the solenoid. This causes the pointer to travel across the scale, from left to right, through a distance proportional to the amount of current flowing in the circuit. The plumb-bob p shown at the extreme right, inside the glass case, is used for "leveling" the instrument, that is, for setting it truly vertical. There are many other forms of

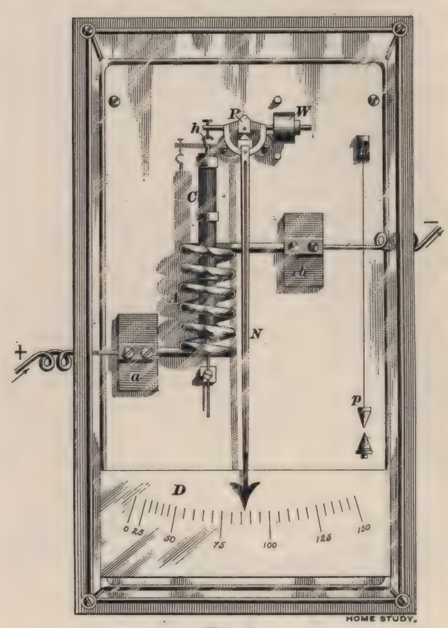


FIG. 4.

ammeters, but those built for practical work usually depend for their operation upon the same principles; that is, the pointer is made to move by being attached to metal which is either caused to turn by a coil or is sucked into a solenoid.

Calibration of a Galvanometer for Volts.—In exactly the same way as an instrument is calibrated for amperes, it may also be calibrated for volts; but in the latter case the galvanometer is calibrated by ascertaining, by special measurements or comparison with a standard instrument, to what number of volts particular amounts of deflection of the pointer correspond. Thus, suppose that it has once been determined that a pressure

of 50 volts causes the needle to deflect through 100 degrees of the scale, then if the instrument remains in the same condition, an electrical pressure of 50 volts will *always* produce that deflection. When, by a series of such comparisons, the various equivalent currents for certain deflections have been determined, the galvanometer scale may be so graduated that the pressure of the current in volts may be read directly from the instrument. Such a galvanometer might be called a *voltmeter*. There are, however, the same objections to its practical use as there are to the galvanometer which is calibrated to *amperes;* and commercial voltmeters, while depending upon the same or similar principles, are differently constructed.

Commercial Voltmeters.—A voltmeter of the same type as the ammeter in Fig. 4 is shown in Fig. 5. The principal difference between the two instruments, and between all ammeters and voltmeters in general, lies in the fact that ammeters are designed to have as *little* electrical resistance as possible, while voltmeters are equipped with *extra* resistance-coils, so as to greatly increase the resistance of the instrument. The reason for this will be explained shortly. The extra resistance-coils are contained in the back of the instrument behind the board R, Fig. 5, and consist of several sheets of card-board (or similar material) upon which are closely wound many hundred feet of insulated thin German silver wire. This wire is all connected in *series* with the solenoid A by means of connections not shown, and the two free ends are brought to the binding posts or terminals, a and b. At F is a fuse which is also connected with the instrument in series and which, by melting when the current accidentally becomes too great, opens the circuit and thus saves the instrument from destruction. The course of the current in the instrument is as follows: Entering the + binding post a, it traverses all the German silver resistance at the back of the instrument; then enters the fuse F, and from there flows into the solenoid. Leaving the solenoid A, the current is carried out of the instrument by the — binding post b, thus completing the circuit. It will be noticed that the solenoid A of the voltmeter is different to the ammeter solenoid shown in Fig. 4. In the voltmeter, the solenoid consists of a hollow coil of thin copper wire, having a great many turns. The action of the instrument is the same, however, as that of the ammeter: Current in the solenoid "sucks" the core in and thus causes the needle N to travel across the scale, which is calibrated to volts.

Comparison of Ammeters and Voltmeters.—From the above we see that ammeters and voltmeters are really identical instruments, with the exception that ammeters are of very low resistance, while voltmeters are of high resistance. That this is so, and the reasons for it, the following considerations will make clear:

In Fig. 6, let D be a dynamo supplying the four lamps L with current. Let it be

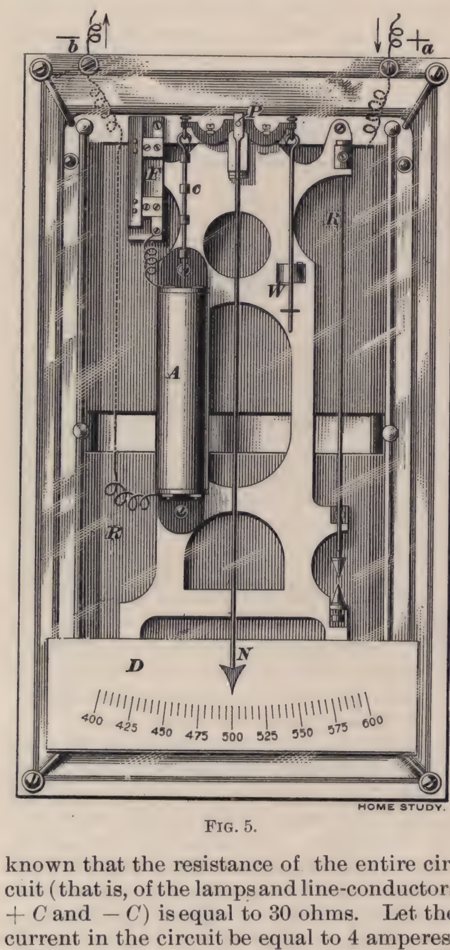


FIG. 5.

known that the resistance of the entire circuit (that is, of the lamps and line-conductors $+C$ and $-C$) is equal to 30 ohms. Let the current in the circuit be equal to 4 amperes, and the pressure of the entire circuit be 120 volts. Then, in order that these values may be indicated correctly, the measuring instruments above described must be used as follows:

I. *Current Measurement.* — The current supplying the lamps L must, after leaving the dynamo, pass to the lamps by way of

the conductor $+C$, and it must return to the dynamo by the conductor $-C$. Furthermore, to measure this current with the ammeter of Fig. 4, we know that the entire current must be made to pass through the solenoid A, which will then exert a certain pull on the core C, thus causing the needle to indicate on the dial the value 120 amperes. To allow all this current to pass through the ammeter, the instrument must be connected in *series* with the circuit. This is done by cutting open the circuit at a point usually near the dynamo, and inserting the ammeter in the gap thus formed. The connections having been made, every variation of current strength in the circuit is indicated upon the dial of the instrument by the varying pull of the solenoid on the core. In Fig. 6, the ammeter, correctly connected, is shown, marked $A.M.$ The rule for this correct connection is, therefore, as follows:

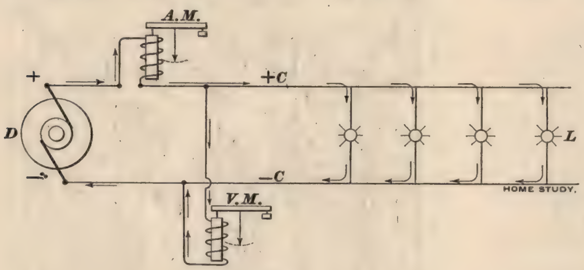


FIG. 6.

Connect the ammeter in such a manner that the entire current of the circuit is made to pass through the instrument.

II. *Pressure Measurements.*—The maximum pressure in any electrical circuit is equal to the sum of all the pressures which are in series with each other. Thus, in Fig. 6 the maximum pressure is equal to the pressure from the positive dynamo-terminal to the lamps, plus the pressure from the positive side of the lamps to the negative side, plus the pressure from the negative side of the lamps to the negative dynamo-terminal; or, in other words, it is equal to the pressure measured across the dynamo-terminals from + to —.

Now, in every electrical circuit, and in every conductor, the pressure is given by formula (1) namely, $E = C \times R$.

If, therefore, we have an instrument, in which R, the resistance, is absolutely constant (that is, never changes in value), then, if this instrument is connected to an electrical circuit, the current C in it will *always* be the same for a given pressure E; and if this pressure should rise around the instrument, the current in the instrument would rise in exactly the same proportion.

Therefore, if we know just what current in the instrument is produced by a certain pressure, we have a measure of this pressure; in other words, a voltmeter. This being the case, the pressure is measured with a voltmeter by connecting the terminals of the instrument around that portion of the circuit for which the pressure is to be determined. Thus, in Fig. 6, where we are desirous of measuring the total pressure, the instruments must be connected *across* the circuit, as shown by $V. M.$ We therefore have the following rule for the correct connection of the voltmeter in any electrical circuit:

Connect the voltmeter in such a manner that its terminals are around that portion of the circuit in which the pressure is to be determined.

Never connect the voltmeter in series, because in that case it acts like an ammeter, and, not having the current-carrying capacity of an ammeter, it will be burned out by the excessive current passed through it.

Conclusions.—From the above we see that since a voltmeter may be required to measure high pressures, as, for instance, in Fig. 6, the amount of current which could thereby be forced through the instrument would be enormous. To prevent this great quantity of current from traversing the voltmeter, a very large resistance is placed in series with it, as explained in connection with Fig. 5. The ammeter, on the other hand, which depends upon the entire current for its action, and which is subjected to a comparatively low pressure only, is designed with its resistance as low as possible, so that no pressure may be wasted in sending the current through it. Thus it is now evident that *the less the resistance of the ammeter and the greater the resistance of the voltmeter, the better, as a rule, are the instruments.*

INCRUSTATION IN STEAM-BOILERS.

W. H. Booth.

Chemical and Mechanical Means of Preventing Boiler-Scale—Three Classes of Injurious Feed-Water—Chemical Composition of Boiler-Scale.

PERHAPS there is no subject which has called forth so much useless discussion or so many worthless nostrums as that of boiler incrustation. The great mistake made by vendors of patent nostrums for preventing or curing scale in steam-boilers is that, having found a certain compound suitable for a certain boiler, they are apt to conclude that the compound is of general utility, and they advocate it *in* season and *out*, utterly disregarding the fact that the conditions vary so much that it is difficult to find even *two* boilers under exactly the same conditions as to feed-water and its necessary treatment; for though the feed may be identical, it is possible that one boiler may have so much more work to do than the other that the compound which suits the lightly-worked boiler will cause foaming in the other, and, consequently, have to be abandoned.

It is therefore desirable that water be analyzed and its constituent impurities ascertained, so that a proper treatment may be accorded it. The means adopted for preventing bad effects from incrustation are either *chemical* or *mechanical*, or both. Chemical means consist of the use of substances which precipitate the solid impurities of the water and allow them to settle in some quiet part of the boiler, whence they can conveniently be blown out.

Mechanical means often depend upon the introduction in the boilers of greasy, starchy, or gelatinous substances, with the intention that as each particle of solid matter is freed from the water it shall become coated with some of the composition and thus prevented from adhering to other particles or to the boiler-plates. Large quantities of mud are formed in this way, which require, for removal, the regular use of the blow-out tap. This is a direct loss in proportion to the amount of hot water wasted by the blow-out, and is opposed to the attainment of economy in fuel combustion. It is not out of place here to inquire into the chemistry of boiler-scale. The guide taken in this article is the treatise on the question by the late Dr. Angus Smith, who made a very careful examination of the whole subject.

He divided waters that are injurious to boilers into three main classes :

1. Alkaline, or chalk, water.
2. Neutral, or gypsum, water.
3. Acid water.

Numbers 1 and 2 are very frequently found together.

Numbers 2 and 3, also, are often found together.

Numbers 1 and 3 cannot be found together, as they would tend to neutralize each other until only one was left.

Now, all such waters are injurious if put into a boiler, the first two because they form scale, and the third because it dissolves the plates.

Chemists tell us that carbonate of lime, which is the solid constituent of water No. 1, is soluble in water only when that water also contains carbonic acid gas in solution ; on boiling the water, the gas is driven off and the carbonate of lime is no longer soluble.

Baron Bunsen determined the solubility of carbonic acid gas in water as 1.7967 volumes at 32°, and only .9014 volumes at 68°, and, whatever the pressure, the dissolved volume of gas remains constant. Hence, the *weight* of gas absorbed is proportional to the pressure. The amount dissolved decreases with rise in temperature, until at boiling-point none is left.

Of the usual impurities in feed-waters, 100 parts of cold water dissolve .0036 of carbonate of lime and as much as .23 of lime sulphate, or gypsum.

At boiling-heat no carbonate remains, but there is still left .21 of the sulphate.

Carbonate of magnesia to the extent of .02 is dissolved cold. This disappears in boiling.

Sulphate of soda is soluble to the extent of 5.02 of the anhydrous salt at 32°, and as much as 50.65 parts at 90°, though 42.65 parts only are soluble at or near boiling-

point, showing a decrease beyond a certain temperature.

Sulphate of magnesia, from having a solubility of 24.7 at 32°, attains, at 222°, as high a solubility as 132.5.

As in the case of carbonate of lime, the presence of carbonic acid is necessary to keep in solution the carbonate of magnesia, a similar salt. As water can be freed from carbonates by boiling, carbonate waters are termed "temporarily" hard, to distinguish them from "permanently" hard, or sulphate, waters.

A carbonate water quickly forms scale, because the whole of its dissolved lime precipitates at once when boiling-temperature is reached, but from this it must not be inferred that sulphate waters do not form scale. They do make a scale, and of a worse nature than a carbonate scale, as will now be shown: After some hours the water in a boiler has changed entirely several times and what is then in the boiler is saturated with all the sulphate left behind. It can then dissolve no further quantity, and scale is formed from that time. Further, when the circulation in a boiler is not rapid and the steam-raising surfaces are near the water-surface, steam is actually formed upon the plates, and, as a molecule of water goes off as steam, it leaves the minutest particle of sulphate right upon the plate ready for instant adhesion, and the scale so formed is very tough and tenacious, more so than a carbonate scale.

The great variety observed in the hardness of scale depends upon the admixture of other substances in the water.

A little clay would probably soften a scale by the particles of clay becoming intermixed with those of the lime salt, and the strength of the scale would be decreased.

Carbonate of lime has the chemical symbol $CaO,\ CO_2$ which shows that it is a compound of lime and carbonic acid. As it exists in water it may be written $CaO,\ CO_2 + CO_2$, the quantity after the sign of addition being the gas which keeps it in solution. If, therefore, to water containing lime carbonate in solution we add plain lime, CaO, which is the oxide of the metal calcium, we cause a peculiar action to take place. The lime absorbs the free gas and the following equation shows what occurs:

$(CaO,\ CO_2 + CO_2) + CaO = 2(CaO,\ CO_2)$.

We have simply absorbed the gas and made more carbonate, which, with the old carbonate already present, will all precipitate. If this process is carried on inside a boiler, the quantity of mud formed will be large, and after all is done in the way of blowing out, we can never prevent some scale from forming.

In boilers of the Lancashire type it is usual for much mud to deposit and harden at the back end of the boiler-bottom; we have seen it there from 6 to 8 inches thick.

If time and space allow, the operation can be conducted outside the boiler and the water cleared by slow settlement and filtration, in which case no scale will be formed in the boiler. In the March number a form of apparatus for this purpose will be illustrated. Another plan has been suggested: the addition of sal ammoniac. Sal ammoniac has the formula NH_4Cl, and the reaction with the lime carbonate is as follows: $CaO, CO_2 + 2(NH_4Cl) = CaCl_2 + (NH_4)_2CO_3$, highly soluble calcium chloride and volatile carbonate of ammonium being formed. The lime chloride can be blown out and the ammonium carbonate goes off with the steam. The danger of this is stated to be a tendency to the formation of hydrochloric acid if the salt is added in excess, the decomposition of NH_4Cl giving ammonia, NH_3, and hydrochloric acid, HCl. The former injures brass or copper and the latter injures the boiler-plates, so that if this method be tried it would be advisable on the last count to make frequent tests of the water drawn from the boiler with litmus paper, which for the water to be safe must be blued by it. If reddened, to correct the evident acidity, we add soda, Na_2O, when the action which occurs is $Na_2O + 2HCl = 2NaCl + H_2O$, or simply common salt and water, which would in time accumulate and require blowing out. In the face of the risk, this method is not to be specially recommended.

The most common present-day practice is the use of soda, NaO_2, either in its anhydrous form or as its caustic hydrate $NaOH$. The effect of this when put into a carbonate water is as follows: $CaO,\ CO_2 + CO_2 + Na_2O = CaO,\ CO_2 + Na_2CO_3$.

The lime falls on the subtraction of the free gas, and carbonate of soda is formed; the latter being very soluble, may be neglected for a long time. This process still leaves the sediment in the boiler to be blown out, and is necessarily accompanied by a waste of hot water.

Turning now to sulphate waters, we have for lime sulphate the chemical formula $CaSO_4$, and it is found that if to water containing gypsum we add carbonate of

soda, or Na_2CO_3, the following reaction takes place: $CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4$.

Of these the first is our old friend, carbonate of lime, which precipitates, and the next is sulphate of soda, which is very soluble and harmless, and may be long neglected.

We notice here, then, a curious fact. When we use plain soda for dealing with lime carbonate, we get as one product carbonate of soda, which is just what is needed for dealing with the lime sulphate. This was first pointed out by Dr. Smith, who argued correctly that in water which contains both carbonate and sulphate there is a double decomposition effected, the soda added doing duty first upon the carbonate, and then, when itself turned to carbonate, proceeding to act on the sulphate, thus turning all the dissolved lime salts to mud and itself becoming sodium sulphate. Of course it is necessary to know, in making use of this double reaction, what the ratio is of carbonate to sulphate in a mixed water. It is not necessary to go deeper into the ratio of the combining weights of lime and soda salts, it being sufficient for our present purpose to know that 100 parts by weight of lime carbonate will call for 80 parts of caustic soda, $2(NaHO)$, to neutralize its suspension and precipitate it, or 62 parts of the anhydrous oxide Na_2O.

Again, 100 parts of lime sulphate call for 78 parts of carbonate of soda to precipitate the sulphate as carbonate. Now, 78 parts of carbonate of soda is equal to 45.6 parts of anhydrous caustic soda and to 59 parts of true caustic, $2(NaHO)$.

The ratio of the caustic soda equivalents in the two cases of lime carbonate and sulphate is 1.36 : 1.00 or 1 : 0.734, that is to say, practically, as 8 to 6. In other words, if a water contains 6 grains of carbonate of lime, the precipitation of this by caustic soda will produce as much carbonate of soda as will then convert 8 grains of lime sulphate into carbonate.

The rules to be followed for different ratios are:

1. Carbonate waters: For each 100 grains of the carbonate of lime add 80 grains of caustic soda.

2. Sulphate waters: For each 100 grains of sulphate of lime add 78 grains of carbonate of soda.

3. Mixture of both lime carbonate and sulphate: For the carbonate add 80 grains of caustic soda per 100 grains, as in rule 1. For the sulphate, subtract from the amount of sulphate per 1,000 gallons, 1.36 times the weight of lime carbonate. If there is any remainder, add 78 grains of carbonate of soda for each 100 grains, as in rule 2. Thus, if the sulphate does not exceed in quantity 8 grains for every 6 grains of carbonate, it may be neglected, for the caustic soda will be sufficient for this when it has done its part on the lime carbonate. In speaking of caustic soda we refer to the substance known as sodium hydroxide ($NaHO$), not to the dry powder formed by oxidizing sodium, which is rarely seen commercially.

The commercial caustic is originally made from carbonate by boiling with quicklime, settling, and evaporating the clear solution, and must not be confounded with soda ash, which is, or ought to be, carbonate of soda. Commercial soda ash often contains as much as 50% of impurities, such as the sulphate, sulphite, and chloride of soda.

Before considering how to prevent scale, it is perhaps as well to state that no amount of treatment with soda will remove deposited lime from the inside of a boiler. What soda can do is to facilitate the separating of carbonate of lime and to change sulphate into carbonate.

Before going further, the third class of water calls for notice, namely, acid water. This is not found to accompany carbonate water, but may accompany water containing sulphates. The reason for this is simple. If acid water is mixed with chalk, or carbonate, water, the acid acts upon the carbonate and converts it into sulphate or chloride, until either the acid is neutralized or the carbonate is wholly converted.

The causes of acidity in feed-water are various and sometimes unexpected.

In one case met with by the writer, the explosion of a steam-boiler could be traced to the unexpected acidity of feed-water. The owners of the boiler—new owners—were men who were working several other boilers with the same stream of water and used little or no soda. They treated their newly acquired boiler in the same manner, and it exploded in a few months from rapid internal corrosion. Investigation by the writer and others revealed the fact that the exploded boiler drew water from a water-wheel by-wash, while the uninjured boilers drew from the same stream 200 yards lower down where the by-wash and main body of the stream had become mixed by passing over a fall. Further search revealed a drain discharging "spent acid" from an electroplating works into the by-wash at the same side as the feed-pipe inlet of the exploded

boiler. This was sufficient to account for the explosion. Below the fall the acid was diluted in the main stream; above, it was stealthily creeping along the bank. There are natural acid waters also. In them the acidity sometimes arises from sulphate of iron, sometimes from vegetable matter. There is one cure for acid water, and it is an easy one; the acidity must be neutralized by adding alkali in sufficient quantity.

This alkali may be lime or it may be soda, and in some waters as much as half a pound of soda carbonate is required for each 1,000 gallons of water; for some large boilers this means a daily addition of from 2 to 4 pounds of soda carbonate. Lime would neutralize double the quantity, but would then go into the boiler and form scale.

It seems reasonable to suppose that when an acid water must be used it would be well to pass it through a filter of limestone chips. These would neutralize the acidity and possibly only become changed by the water and not dissolved and carried away with it. In any case, to prevent rapid corrosion by the water it must be served with sufficient alkali to cause it to produce the blue reaction on litmus paper.

As regards the final removal of scale or mud, there are two opinions. One is that the removal of sediment after treatment should take place *outside* the boiler; the other, that the sediment should be removed from the *inside* of the boiler.

In the March number various methods will be explained and illustrated.

PAVEMENTS.

Benjamin F. La Rue.

WHAT CONSTITUTES A SATISFACTORY PAVEMENT—THE WEARING-SURFACE, BASE, AND NATURAL FOUNDATION—QUALITIES ESSENTIAL TO AND MATERIALS SUITABLE FOR EACH.

WITH reference to the purposes for which they are used, pavements may be considered to be of two general classes, namely, roadway pavements and footway pavements. It is desirable that the pavement for a roadway should possess a smooth, even, and reasonably hard surface, affording easy and comfortable transit for vehicles at any ordinary speed, and that footway pavements should be of such a character as to be easy and pleasant to walk upon. We all recognize a satisfactory roadway pavement when we ride over it, and a suitable footway pavement when we walk upon it, but we are not generally familiar with the conditions essential to a properly constructed and satisfactory pavement of either kind. Indeed, comparatively few of us understand of what a pavement really consists, further than that we are able to name the material in the surface of those pavements with which we are familiar. In the present article we will endeavor to learn something about the essential parts of, and the conditions requisite to, a suitable roadway pavement.

Pavements are for the purpose of improving the facilities for, and reducing the expense of, the transportation of merchandise and all industrial products, and for increasing the safety, speed, comfort, and pleasure of travel. Such are the purposes for which they are constructed, and for any particular case, the pavement that will meet these conditions most effectually and with the greatest degree of economy, will be the best and most suitable. It should afford a smooth, even surface, offering the least possible resistance to traction and over which vehicles may pass with ease, safety, and comfort, and should, at the same time, furnish an impervious covering that will protect the soil of the natural foundation; it should also have strength to distribute the weight of the loads concentrated upon the wheels over sufficient areas of the natural foundation to be supported without destructive effect upon that foundation. This is necessary in order that the pavement may retain its smooth and even surface.

In the construction of a pavement we have to deal with three different, and more or less distinct, features, namely, the *wearing-surface;* the *base*, or *artificial foundation;* and the *natural subsoil foundation*, or *roadbed.* The first two are integral parts of the artificially constructed pavement, while the last generally consists of the bed of natural earth, or subsoil, upon which the pavement

rests, although, where the natural soil is very unstable, this foundation, also, is sometimes artificially prepared.

The wearing-surface is the upper layer of material which constitutes the finished surface of the roadway and which sustains the traffic; it is that visible portion of the pavement with which we are familiar, and by which the traffic is directly affected. In order that this wearing-surface may be satisfactory for public travel, there are certain qualities which it should possess.

It should be *impervious* to water or other liquids that may fall upon or flow over its surface, and its surface should be of such form as to promptly discharge them into the side gutters and drainage outlets.

It should be *hard*, *tough* and *durable*, so as to resist the wear of the traffic and the disintegrating effect of the elements.

It should be *smooth* and *even*, so as to offer the minimum resistance to traffic, and, at the same time, should be of such a character as to afford a secure foothold for horses, and one which will not become polished and slippery from use.

It should be comparatively *noiseless*, of such a character as to yield very little dust or mud, and should be *easily cleaned*.

It should be adapted to the grades and suited to the traffic.

There are a number of different kinds of material that fill the above requirements more or less perfectly, and that have proved reasonably satisfactory. Others have also been tried, but have not proved suitable. The following materials have been quite extensively used, namely: *asphalt*, *bricks*, *stone blocks*, *wood blocks*, *cobblestones*, and *broken stone*. These materials are named in about the order of their comparative merits, although the true value of any one of them depends largely upon the character of the traffic to which it is subjected. For instance, if the pavement is subjected to a constant and exceedingly heavy traffic, granite blocks will be the best material for the wearing-surface; for a residence street, having a moderate traffic of reasonably light character, with more or less pleasure-driving, asphalt may be the best. Most of the materials named above have proved reasonably satisfactory for the wearing-surfaces of properly constructed pavements where the traffic is of the character to which the material is adapted.

As the surface is the only part of a completed pavement that is visible, we very naturally designate the pavement by the name of the material constituting its wearing-surface, and we are very apt also to consider the wearing-surface to be in all respects representative of the entire pavement. We not uncommonly attribute the condition of a pavement, and whatever of merit it may possess, wholly to the wearing-surface; if the pavement has proved satisfactory, we generally think that another pavement, having a wearing-surface composed of the same material, would be equally satisfactory; and if the pavement has not proved satisfactory, we are inclined to condemn all pavements having wearing-surfaces of the same material.

This idea, though quite common, is very erroneous. The wearing-surface is a very essential part of any pavement, and none can be satisfactory unless this portion of it is formed of suitable material and is properly constructed. Though it be ever so well constructed, however, the wearing-surface cannot satisfactorily sustain the traffic without being in turn supported by a firm and unyielding foundation, any more than the superstructure of a building can support its contents and retain its proper form unless it is upheld by a suitable foundation, or than a vehicle that is mounted on broken wheels can be a satisfactory means of transportation.

As a matter of fact, the wearing-surface of a pavement is properly little *more* than a surface, and, of itself alone, is not capable of sustaining traffic and distributing weight over a sufficient portion of the yielding soil beneath it. It is, therefore, necessary that the wearing-surface of any pavement should rest upon, and be sustained by, a foundation having sufficient strength to resist deformation from the concentrated loads of the traffic, and it should also distribute the loads over sufficient areas of the underlying soil so that the soil will not be unevenly compressed or distorted, but will sustain the loads without injury. In any pavement, the value and condition of the wearing-surface, and, consequently, of the pavement as a whole, will depend largely upon the efficiency of the foundation. It is thus seen that a well-constructed foundation of suitable material is very essential.

The materials commonly used for the foundations are *hydraulic cement concrete*, *bituminous concrete*, *broken stone*, *bricks*, *gravel*, *sand*, and *plank*. Here, again, the materials are named in the order of their respective merits. Hydraulic cement concrete, composed of hydraulic cement, sand, and broken

stone, forms, when it has become thoroughly set, a solid, unyielding foundation that is also impervious to water; it very efficiently distributes the loads upon, and protects, the underlying soil of the natural foundation; the same is, to a less extent, true of bituminous concrete, which is commonly composed of coal-tar residuum, creosote-oil and broken stone. Bricks, broken stone, gravel and sand all form, under suitable conditions, reasonably solid, but not impervious foundations, while foundations formed of planks are neither unyielding nor impervious. Plank foundations, as usually constructed, are not capable of distributing the loads concentrated upon the wheels over sufficient areas of the underlying soil to prevent the latter from being unevenly compressed; depressions are formed in the subsoil by the passage of heavy loads, which not only allow the planks to spring with the passage of all subsequent loads, thus disturbing and destroying the form of the wearing-surface, but also retain water and tend to further destroy the natural foundation. Plank foundations form at best but temporary expedients; under the usual conditions they soon decay and become even worse than useless.

The soil of the natural foundation should consist of suitable material. Hardpan, gravel, and sand are the best materials; clay is good if well drained; any ordinary earthy material is generally satisfactory if free from decaying vegetable matter; humus, or vegetable mold, is not suitable. Where the natural soil is unsuitable, it is usually necessary to excavate it to a considerable depth and fill in with suitable material, such as gravel, sand, or hardpan; a mixture of gravel or sand with clay forms a good material for this purpose.

In the accompanying illustration is shown the cross-section of a brick pavement. The wearing-surface *b* is composed of bricks set on edge upon the layer of concrete *c*, which is spread upon the natural earth foundation *e*. The curbing *k* consists of thin slabs of stone set along the edges of the roadway to define its boundary and serve somewhat as a retaining wall for the adjacent earth. The flagstone *f* of the sidewalk rests directly upon the layer of sand *s*, which is spread upon the natural earth foundation *e*, and acts somewhat as a cushion to distribute and equalize the pressure.

THEORY AND PRACTICE.

THEORETICAL AND PRACTICAL FORMULAS—RULES OF THUMB NOT PRACTICAL FORMULAS—THEORY AS A TEST, SAFEGUARD, AND GUIDE—RIVETED JOINTS AS AN EXAMPLE.

THE controversy between theory and practice in the machine-shop, or between the drafting-room and the shop, or the college-graduate engineer and the practical machinist, is as old as the art of machine-building. There is no doubt that machines were built long before theory gave us the reasons for the results obtained, and long before the age of formulas. Among the artisans of old, rules always existed, deviating from which would have been dangerous in many ways, and those rules were, in the majority of cases, so well established by the results obtained that their correctness could not and cannot to-day be questioned; they have stood the test of theoretical investigation since. But there have been other rules, long cherished ones, many of which are still lingering in the minds of some people, rules that theory has no explanation for. These are the "rules of thumb." While a purely theoretical solution of even the simplest problem in the mechanical arts must necessarily be incomplete on account of the utter impossibility of theoretically considering each and every secondary influence bearing on the final result, theory is the only test, safeguard, and guide for our practical rules. The "theoretical formula" forms as it were the skeleton upon which practical experience builds the flesh which must be added to complete the body, and the result is the "practical formula," which takes account of all minor details and allows for all those secondary influences which theory had overlooked, either purposely, to avoid too complicated a formula, or without purpose, in cases where the true cause of a certain effect had not been recognized. The more thoroughly theory investigates causes and subsequent effects, the more closely do its formulas tally with those obtained by practical methods, until finally the ideal "theoretical" formula becomes at the same time the ideal "practical" one. Of these there are at present very few. It is hoped, however, that there will come a time when eternal peace will reign between theory and practice, and when there will be no more mysterious rules of thumb that cannot be made transparent even to the strongest X-rays that science can produce.

In order to illustrate the above, there are given below a number of practical formulas and tables relating to riveted lap-joints—a subject that is generally among the first to be treated in text-books on machine design; and a few remarks pointing towards the theories involved are added. The tables are considered as embodying the best practice and are valuable, therefore, to the practical machinist in laying out such work.

In every case the thickness t of the shell is given, and upon this the other data are dependent. Commencing with the dimensions e, Fig. 1 (the distance of the center line of rivets from the edge of each plate) these must be such as to ensure safety against the breaking of the plate as indicated at A. A simple theoretical formula for calculating the values of e cannot well be given, as the strains and stresses at these points are complicated on account of calking. It is an ordinary practical rule to make e equal to $1\frac{1}{2}$ times the diameter d of the rivet; for thin plates this may be somewhat increased, say to $1\frac{5}{8}$ times the diameter of the rivet. Too wide laps make it difficult to calk the joints, but, nevertheless, some advise as wide a lap as 3 to $3\frac{1}{2}$ times the diameter. The diameters of the rivets should be such as to be secure against crushing as well as shearing. The diameters d given in Table I are safe against crushing, and if the proper pitch, or distance between rivets, is chosen, they will also be safe against shearing. The diameter of rivet can be found by theoretical deduction, taking into account the fact that there is a limit to the size of hole which it is possible to punch; or, in other words,

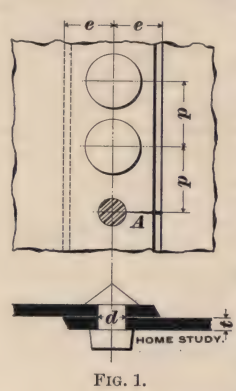


FIG. 1.

that, if the diameter of the punch is smaller than a certain limit, the punch will be crushed. As, however, much diversity of opinion exists as to the "standing quality" of a punch, it will be evident that a theoretical formula thus evolved would not be satisfactory. A practical rule however is the following: $d = \frac{7}{8}t + \frac{3}{8}''$. By this formula the values in Table I have been calculated.

TABLE I.

t	d
Inch.	Inch.
$\frac{3}{16}$	$\frac{1}{2}$
$\frac{1}{4}$	$\frac{9}{16}$
$\frac{5}{16}$	$\frac{11}{16}$
$\frac{3}{8}$	$\frac{3}{4}$
$\frac{7}{16}$	$\frac{13}{16}$
$\frac{1}{2}$	$\frac{13}{16}$
$\frac{9}{16}$	$\frac{7}{8}$
$\frac{5}{8}$	$\frac{15}{16}$
$\frac{11}{16}$	1
$\frac{3}{4}$	$1\frac{1}{16}$
$\frac{13}{16}$	$1\frac{1}{16}$
$\frac{7}{8}$	$1\frac{1}{8}$

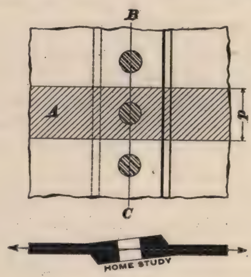


FIG. 2.

To prevent the bursting of the shell along the center line of the rivets, the distance between the latter—or the pitch p—must be large enough. Theory says as follows: Take a strip A of the width p. (See Fig. 2.) The ends of this strip are held together at the joint by one rivet. Suppose sufficient force is applied to tear the joint apart, then, either the rivet will be shorn off or the plate will burst along the center line $B\,C$. To give equal chance to both elements, the shearing strength of the rivet must be equal to the tensile strength of the metal of the plate on both sides of the rivet-holes $(p - d)$. Now it is very easy to make up the following equations:

$$a \times S_s = A \times S_t.$$

in which a = cross-sectional area of rivet;
A = cross-sectional area of plate between two rivet-holes = $(p - d) \times t$;
S_s = shearing strength of material of rivet per square inch;
S_t = tensile strength of material of plate per square inch.

$$a \times S_s = (p - d) \times t \times S_t.$$

$$\frac{a \times S_s}{t \times S_t} + d = p.$$

If the tensile strength of the material of the plate is known, either from its being stamped on the plate, as is often done, or by actual testing, and if the shearing strength of the rivet material is also known, the above formula seems at once serviceable. But it is a purely theoretical formula and, as is to be expected, does not allow for various minor influences which are at work on the final result. As will be seen from Fig. 2, it is necessary, first, to make allowance for the fact that the plate at a lap-joint is subjected, not to a straight pull, but to an oblique one and has therefore to resist a force which tends to bend it. We cannot therefore insert the full tensile strength in our formula, but must use a smaller amount. Thus, if a material has by test a tensile strength of 45,000 pounds, it will be well to substitute 40,000 in the formula. Punching the holes will also have some effect on the strength of the plate, the material being crowded up around the edge of the hole. Annealing rectifies that however to a great extent. Fig. 2 also shows that the rivet is not subjected to a shearing stress pure and simple, but to tension as well. It will be advisable, therefore, to modify the constant for S_t also. It must further be remembered that it makes a great difference whether the rivet-holes are punched or drilled. 46,000 pounds per square inch is a good value for iron rivets in punched holes. With these values, then, our formula now reads

$$\frac{a \times 46{,}000}{t \times 40{,}000} + d = p.$$

Table II has been originally calculated from this formula, but the figures for p have been still more "rounded off," so as to increase more uniformly with the thickness of the plates.

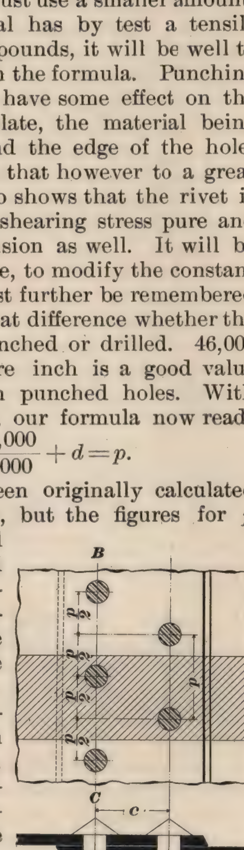


FIG. 3.

The original formula having been so much modified, it is not considered by many anything out of the way to go one step further for simplicity's sake and to assume $S_s = S_t$, which makes the formula look like this:

$$\frac{a}{t} + d = p.$$

From this, Table III has been calculated. The assumption that $S_s = S_t$ is not necessarily arbitrary, however, as, in cases where the holes are drilled in iron plates, this condition approximately exists. The figures in Table III are also better suited for steel plates and iron rivets.

TABLE II.

Single-riveted lap-joints for wrought-iron plates, holes punched, not annealed.

t	d	p
Inch.	Inch.	Inch.
$\frac{3}{16}$	$\frac{1}{2}$	$1\frac{1}{2}$
$\frac{1}{4}$	$\frac{9}{16}$	$1\frac{3}{4}$
$\frac{5}{16}$	$\frac{11}{16}$	2
$\frac{3}{8}$	$\frac{3}{4}$	$2\frac{1}{8}$
$\frac{7}{16}$	$\frac{13}{16}$	$2\frac{1}{4}$
$\frac{1}{2}$	$\frac{13}{16}$	$2\frac{3}{8}$
$\frac{9}{16}$	$\frac{7}{8}$	$2\frac{1}{2}$
$\frac{5}{8}$	$\frac{15}{16}$	$2\frac{5}{8}$
$\frac{11}{16}$	1	$2\frac{3}{4}$
$\frac{3}{4}$	$1\frac{1}{16}$	$2\frac{7}{8}$
$\frac{13}{16}$	$1\frac{1}{16}$	3
$\frac{7}{8}$	$1\frac{1}{8}$	3

TABLE III.

Single-riveted lap-joints for wrought-iron plates, holes drilled, or steel plates with iron rivets.

t	d	p
Inch.	Inch.	Inch.
$\frac{3}{16}$	$\frac{1}{2}$	$1\frac{1}{2}$
$\frac{1}{4}$	$\frac{9}{16}$	$1\frac{5}{8}$
$\frac{5}{16}$	$\frac{11}{16}$	$1\frac{3}{4}$
$\frac{3}{8}$	$\frac{3}{4}$	$1\frac{7}{8}$
$\frac{7}{16}$	$\frac{13}{16}$	2
$\frac{1}{2}$	$\frac{13}{16}$	$2\frac{1}{8}$
$\frac{9}{16}$	$\frac{7}{8}$	$2\frac{1}{4}$
$\frac{5}{8}$	$\frac{15}{16}$	$2\frac{3}{8}$
$\frac{11}{16}$	1	$2\frac{1}{2}$
$\frac{3}{4}$	$1\frac{1}{16}$	$2\frac{5}{8}$
$\frac{13}{16}$	$1\frac{1}{16}$	$2\frac{5}{8}$
$\frac{7}{8}$	$1\frac{1}{8}$	$2\frac{3}{4}$

TABLE IV.

Double-riveted lap-joints for wrought-iron plates, punched holes, not annealed.

t	d	p	c
Inch.	Inch.	Inch.	Inch.
$\frac{3}{16}$	$\frac{1}{2}$	2	$1\frac{3}{4}$
$\frac{1}{4}$	$\frac{9}{16}$	$2\frac{1}{8}$	$1\frac{7}{8}$
$\frac{5}{16}$	$\frac{11}{16}$	$2\frac{1}{4}$	2
$\frac{3}{8}$	$\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{3}{16}$
$\frac{7}{16}$	$\frac{13}{16}$	$2\frac{3}{4}$	$2\frac{3}{8}$
$\frac{1}{2}$	$\frac{13}{16}$	3	$2\frac{9}{16}$
$\frac{9}{16}$	$\frac{7}{8}$	$3\frac{1}{4}$	$2\frac{13}{16}$
$\frac{5}{8}$	$\frac{15}{16}$	$3\frac{1}{2}$	3
$\frac{11}{16}$	1	$3\frac{5}{8}$	$3\frac{1}{8}$
$\frac{3}{4}$	$1\frac{1}{16}$	$3\frac{3}{4}$	$3\frac{1}{4}$
$\frac{13}{16}$	$1\frac{1}{16}$	$3\frac{7}{8}$	$3\frac{3}{8}$
$\frac{7}{8}$	$1\frac{1}{8}$	4	$3\frac{1}{2}$

For double-riveted lap-joints our last formulas evidently take the following forms:

$$\frac{2a + 46{,}000}{t + 40{,}000} + d = p\,; \quad \frac{2a}{t} + d = p,$$

as can easily be seen from Fig. 3, following the same reasoning as before in dealing with the single joint. Tables IV and V give good practical values for p.

It remains to say something about the values of c, the distance between center lines of rivets. These have been chosen simply so that each rivet lies outside of two circles drawn around the two adjoining rivets with a radius equal to $\dfrac{p}{2}$ as shown in Fig. 4.

FIG. 4.

TABLE V.

Double-riveted lap-joints, for wrought-iron plates, drilled holes or steel plates with iron rivets.

t	d	p	c
Inch.	Inch.	Inch.	Inch.
$\frac{3}{16}$	$\frac{1}{2}$	2	$1\frac{3}{4}$
$\frac{1}{4}$	$\frac{9}{16}$	$2\frac{1}{8}$	$1\frac{7}{8}$
$\frac{5}{16}$	$\frac{11}{16}$	$2\frac{1}{4}$	2
$\frac{3}{8}$	$\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{3}{16}$
$\frac{7}{16}$	$\frac{13}{16}$	$2\frac{5}{8}$	$2\frac{5}{16}$
$\frac{1}{2}$	$\frac{13}{16}$	$2\frac{3}{4}$	$2\frac{3}{8}$
$\frac{9}{16}$	$\frac{7}{8}$	$2\frac{7}{8}$	$2\frac{1}{2}$
$\frac{5}{8}$	$\frac{15}{16}$	3	$2\frac{9}{16}$
$\frac{11}{16}$	1	$3\frac{1}{8}$	$2\frac{3}{4}$
$\frac{3}{4}$	$1\frac{1}{16}$	$3\frac{1}{4}$	$2\frac{13}{16}$
$\frac{13}{16}$	$1\frac{1}{16}$	$3\frac{3}{8}$	$2\frac{15}{16}$
$\frac{7}{8}$	$1\frac{1}{8}$	$3\frac{1}{2}$	3

The foregoing illustration shows how much practical rules deviate from the results of theoretical calculations; it shows also, however, that the latter are the true starting-points—the foundations to build on with practical experiments. The same principle should be followed throughout the whole field of machine-designing. There are even many cases where a calculation beforehand is out of the question, where one must almost lay out the whole machine by intuition and then go over it with the magnifying-glass of theory, and add where we find too little and take off where we find too much.

WATER-GAS.

George F. Lord.

Its Manufacture—How it is Purified—Wet and Dry Meters—Analysis of the Gas-Flame—Principle of the Bunsen Burner.

Ancient philosophers regarded fire and water as two elements which were in direct opposition to each other. But modern science has demonstrated that water can be decomposed into two gases, one of which will burn; and again, that water is one of the products of combustion. For experimental purposes, the decomposition of water into hydrogen and oxygen is effected by *electrolysis*—a method fully described in Home Study Magazine for December, 1896. We will now describe the commercial process employed in the manufacture of hydrogen- or water-gas—explaining how it is made to furnish light and heat for public use.

The first operation is carried on in the "generator." This is practically a large receptacle or fire-pot, so constructed that it can be hermetically sealed at the bottom, in order to prevent the entrance of air. It is filled with a mass of anthracite coal—technically called a "charge." This is fired and brought to a state of incandescence through the aid of a blast of air from a blower. This is the only draft that the fire receives, since the generator is sealed. The heated gases—the product of this vigorous combustion—pass upwards through the "superheater" or "regenerator." Here they meet with a surface of hot brickwork, arranged in a checkered fashion in order to expose the ascending gases to a large heating area. The air-blast is continued until, on looking through the peephole at the side of the regenerator, these bricks are seen to be very highly heated. The air-valve is then closed and a jet of steam is forced upward through the glowing coal. The heated carbon, searching for oxygen, cannot find it in a free state now that the air-blast is shut off, so it takes it from the steam, uniting with it to form carbon dioxide (CO_2) and liberating the hydrogen. But in passing through the remainder of the glowing coal, the greater part of the CO_2 loses one more atom of oxygen and becomes carbon monoxide (CO). This is the gas which burns with a pale blue flame on the top of a freshly-coaled fire. It is the result of carbon burning in an insufficient supply of oxygen.

The gases, then, which pass upwards into the regenerator are hydrogen, carbon monoxide and carbon dioxide; and, in addition to these, there are sulphur gases formed from the impurities in the coal. As all these gases enter the lower end of the regenerator, they meet with a spray of petroleum, which is forced in by a small jet of steam. The purpose of this petroleum is to furnish carbon to the gas, petroleum itself being what is called a hydrocarbon, that is, composed largely of hydrogen and carbon. Now, hydrogen alone is not an illuminant; it

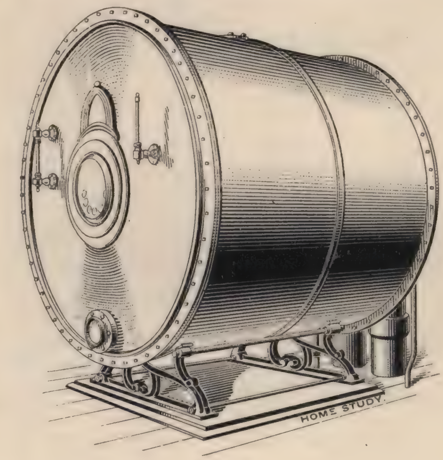


Fig. 1.

burns with a pale blue flame. Every illuminant, whether candle, lamp, gas, or electric, depends upon incandescent carbon for its luminosity; carbon, then, is added to the gas to make its flame luminous.

The gases mingle with the petroleum spray and rise to the surface of the heated brickwork. Here the intense heat volatilizes the oil, which becomes chemically changed into various gaseous and tarry products.

After the steam-blast has been in operation for about 20 minutes, it is necessary to reheat the apparatus, so the steam-valve is closed and the air-valve opened. One charge of coal lasts through two complete charges of steam and air, or about 80 minutes. These figures vary considerably under different circumstances. The quantity of gas liberated at each coal charge is from about 12 to 15 thousand cubic feet. In the 24 hours of a winter's day, about 10 charges of coal are used.

The chemical action which takes place in the regenerator is called "fixing the gas." This hot fixed gas contains some tarry products which are condensable. These must be removed, or the gas-pipes would soon become choked. So the gas is passed through a sort of trap, filled with water. This cools it somewhat and also prevents any backward rush. It then enters what is called a "scrubber." There are various forms of scrubbers, but the main principle of them all is to bring the gas in contact with a constantly renewed supply of cold water. The cooling condenses the heavy tars and they flow out at the bottom of the scrubber. The gas is then passed through other condensers, similar in construction to the ordinary upright tubular boiler. The hot gas passes through the tubes, entering them at the top and passing out at the bottom. These tubes are surrounded by cold water, which enters at the bottom, under pressure, and flows out at the top. From one condenser the gas passes on to a second and sometimes to a third, and when it makes its final exit, it is quite cool.

The gas next passes into a system of pipeworks, through which it is diverted by means of valves into the purifiers. These purifiers consist of large flat iron boxes. They are arranged in sets of four. Three of them are always in use, the fourth being kept for a change-off during the cleaning of any one of the other three. Each box contains a mixture of oxide of iron, lime, and sawdust. The sawdust has no chemical effect, being added merely for the sake of keeping the lime and oxide of iron in a state of mechanical separation. The lime unites with the carbon dioxide and forms calcium carbonate. It also takes up some of the sulphur, forming sulphide of calcium. The remaining sulphur compounds are taken up by the iron oxide, and form sulphide of iron. The gas is now ready for use and passes into the station meter.

This consists of a large cylindrical vessel about 10 feet in diameter and 15 feet long. An exterior view is shown in Fig. 1. The interior is represented in Fig. 2. The vessel is a little more than half-full of water. The gas enters at *P* above the surface of the water, and passes into one of the four partitions of the drum, as shown. Its exit is cut off at *C* by the water, so it raises the partition; in other words, it causes the drum to rotate in the same direction as the hands of a clock. As the outer end of the partition emerges from the water at *D*, the gas escapes into the space between the drum and the external cylinder and passes out through a pipe not shown in the figure. This instrument is known as a wet meter and is an accurate index of the output of the

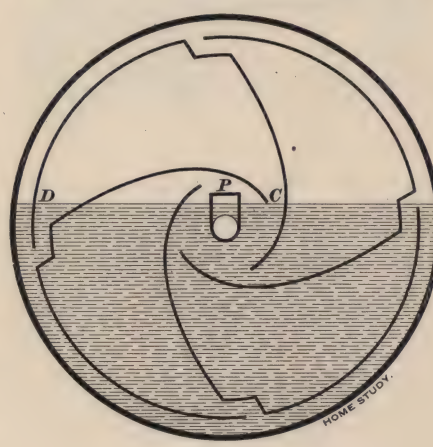


FIG. 2.

works, for it is operated entirely by the pressure of the gas; and since each partition holds a known amount, the total volume which passes through the meter may be measured by recording the number of revolutions. This is done by a mechanical counting device attached to the cylinder, the dials in front recording the number.

After escaping from the meter, the gas flows through pipes to the gas-holder shown in Fig. 3. This consists of an inverted vessel of sheet iron, which floats in a tank of water, and rises and sinks as the volume of gas in it varies. The pipe through which the gas enters, opens above the surface of the water, and another pipe placed on the opposite side provides for its exit. As the holder rises and falls, it is kept in position by the rollers or pulleys shown in the figure. The modern gas-holder is a triumph of mechanical skill. Much ingenuity has been expended in constructing a holder which would have the necessary strength, and still

be of light weight. There may be several cylinders, or lifts. As soon as one is filled, it hooks into a projecting flange on the next lower one and raises that. It is a very important part of the gasworks, as it accomplishes several purposes. It stores the gas

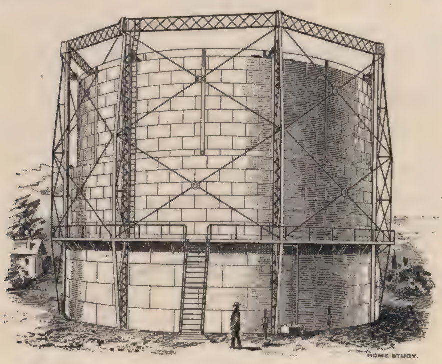


FIG. 3.

that is manufactured during the part of the day when there is little demand, and, when the gas is in use, forces it out with a nearly constant pressure by reason of its own weight. It also *mixes* the gas from different charges so that the product as sent through the mains will be of uniform illuminating power.

The amount of pressure in the mains is regulated by the "station governor." This instrument is so delicately constructed that the opening of 20 burners on the mains will cause it to automatically increase the supply. Near the governor is a **U** tube containing water. One arm is open to the air, and the other is subject to the pressure of the gas. The difference in height of the two columns indicates the pressure. In the office, an automatic register and pressure-gauge are in sight of the superintendent. These read the same as the **U** tube in front of the governor, and a breakdown is immediately discovered.

From the governor the gas passes out through the mains. Sometimes, when the mains extend a great distance from the works, an auxiliary holder is constructed, which regulates the pressure for that district. At the consumer's the gas is again measured by a small dry meter.

Let us now examine the flame of the burning gas. Just above the tip is the blue space marked *H* in Fig. 4. If we insert the end of a glass tube into this space, we may observe a deposit of water near the upper end. On the approach of a match the issuing gas will ignite. This blue area of intense heat and low illuminating power is burning hydrogen. It unites with the oxygen of the air and forms water, which condenses in the upper part of the tube. Along with the hydrogen come the hydrocarbons. They are decomposed in the dark space just above *H*—marked *C*—and the carbon is free. During its passage through the flame, it becomes incandescent, and then unites with the oxygen of the air to form carbon dioxide. When there is an excess of carbon or a deficiency of oxygen, all the carbon is not consumed, and it escapes in the form of soot. The dark fringe around the flame is caused by the condensation of the carbon as it meets with the cool air. If we raise the tube from its first position, until the end lies in the area of illumination, the little flame will go out, and in its place we will have smoke.

If a cold glass plate is brought near the top of the flame, a band of soot will be deposited upon its surface. If now we take a tube and blow through the flame horizontally at *H*, the entire flame will become blue. If we now hold the cold plate near this flame, no soot will be deposited, showing that the carbon has all been consumed. If a wire is held in this blue flame, it will become white hot in a few seconds, owing

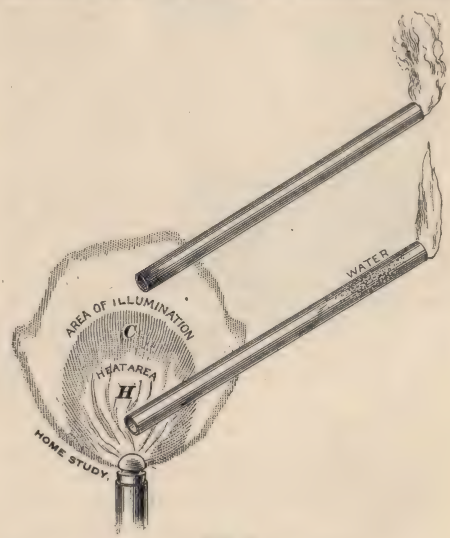


FIG. 4.

to the intense heat produced by bringing plenty of oxygen to the flame, and consuming all the carbon. This is the principle of Bunsen burners and gas-stoves, in which air is admitted to the gas-pipe before it reaches the burner, is drawn along by the

motion of the gas, and furnishes to the flame an abundant supply of oxygen. The new gas-burner of the Welsbach type consists of an incombustible ash mantel which is heated to incandescence by a small Bunsen burner.

The rapid introduction of electricity as an illuminant has stimulated the gas manufacturer to the production of a better quality of gas, and the provision of means for its economical use, both as an illuminant and as a heating agent, and the time is possibly not far distant when gas will be used instead of coal or wood, for cooking our food and warming our homes.

THE ATMOSPHERE.

G. H. Dimpfel, Ph. D.

Its Composition and How Determined—Our Breathing Organs—We Live at the Bottom of an Aerial Ocean—Deep-Sea Fish—Ballooning.

OF ALL our surroundings, we are probably most familiar with that invisible something which we call *the atmosphere,* and which we are industriously engaged in pumping into our lungs "for dear life," every moment of our existence.

The atmosphere is the aerial envelope which surrounds the earth, and constitutes the ocean of air at the bottom of which we are living. The exact height of the atmosphere is unknown; it is generally given as from 30 to 35 miles; observations, however, upon the zodiacal light and meteoric showers lead us to believe that it may be from 50 to 60 miles.

Thanks to certain self-acting arrangements in the nervous system of the animal organism, the respiratory organs work mechanically and perform their unceasing labors so quietly and regularly that, as a matter of fact, we scarcely give a thought to them, unless, in some way or other, they get out of order. It hardly ever occurs to us that we are living and breathing at the bottom of an immensely deep aerial ocean, deeper and wider to an enormous extent than the watery oceans we are familiar with, and agitated by tides and currents and furious whirlpools, compared to which the disturbances of the watery oceans are the merest pigmies.

The first question which occurs to the thinking mind is, of what is this immense aerial ocean composed; what are the gases and what their proportions?

The exact composition of the atmosphere has repeatedly been made the subject of experimental research. It has been found that the air is a mixture of oxygen and nitrogen in the proportion, according to Dumas and Boussingault, of 23.13 of oxygen to 76.87 of nitrogen. It also contains a little less than 1 per cent. by volume of a gas, the existence of which has been recently discovered by Lord Rayleigh and Professor Ramsey, and named by them *argon;* traces of carbonic acid gas, and a variable proportion of vapor of water; in addition to these it contains traces of ammonia, and, under certain conditions, a little hydrogen disulphide.

Air has been brought from the lofty Alpine heights, and from the dry, overheated plains of Egypt; it has been brought from an elevation of 21,000 feet by the aid of a balloon; it has been examined in large cities, such as London and New York, and in small, out-of-the-way country places; still, astonishing as it may seem, the proportion of oxygen and nitrogen remains pretty nearly always constant. The presence of carbonic acid gas, however, being caused by local influences, varies somewhat.

That the atmosphere is a purely mechanical mixture of gases, and not a chemical compound, has and can be ascertained as well by analysis as by synthesis. The former method is the one by which Lavoisier first established the composition of air. His experiment, now a classic one in chemistry, was performed in the following way: A glass balloon with a long neck, as shown at *a* in Fig. 1, was partially filled with mercury. This was heated. The neck passed down under the surface of the mercury in an adjoining trough *b* and then up into a bell-glass *c*—also full of air—whose mouth was sealed by the mercury. On raising the temperature of the mercury in *a* to near the boiling-point, a red powder began to

accumulate upon its surface, the volume of the air in c at the same time proportionally diminishing, until, at the end of twelve days, the contraction of volume ceased, and the experiment was concluded. The gas contained in the apparatus was found to be nitrogen ; and, by collecting the red powder

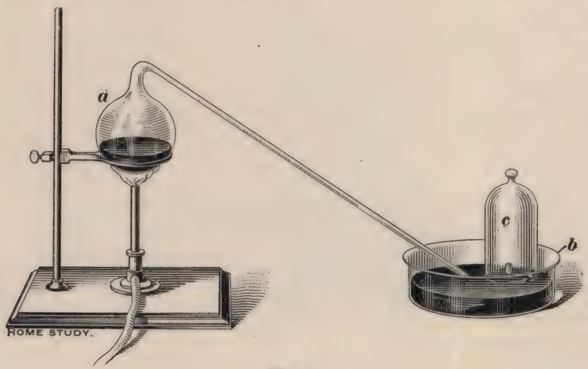


FIG. 1.

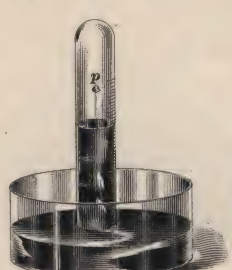
and heating it, the mercury was reproduced and a gas evolved, which proved to be oxygen.

This experiment, however, was purely qualitative, proving only the broad fact that air consisted largely of oxygen and nitrogen, mechanically mixed. An approximate quantitative experiment may be easily performed by taking a graduated tube full of air, placing in it a piece of phosphorus p, Fig. 2, fastened to the end of a wire, and immersing the mouth of the tube in a bowl of mercury. By the slow combustion of the phosphorus, the oxygen will be removed from the air, and the mercury will naturally rise to fill the space which the oxygen had previously occupied. The nitrogen will be left in the tube. Knowing the original volume of the air, its composition may be easily calculated from the increased volume of the mercury in the graduated tube.

A far more accurate quantitative analysis of air, however, may be made by means of a piece of apparatus known as an *eudiometer* (see Fig. 3). A measured quantity of air is placed in a eudiometer, and hydrogen is added in excess of that necessary to combine with the whole of the oxygen present ; on the passage of an electric spark, union of hydrogen and oxygen is effected, and on the gas regaining its original temperature, the volume is found to be much less. As water is composed of 2 volumes of hydrogen to 1 of oxygen, the amount of oxygen present in the gaseous mixture is one-third of the diminution observed. The eudiometer employed for this purpose should, of course, be graduated. Supposing that 10 cubic inches of air have been introduced and 5 cubic inches of hydrogen added ; after the explosion the volume will be found to be reduced from 15 to about 9 cubic inches ; 10 cubic inches of air, therefore, contain $\frac{6}{3} = 2$ cubic inches of oxygen.

The composition by weight is most exactly ascertained by passing air over red-hot copper, due precautions being taken to avoid error. The copper is placed in a piece of glass tubing, as shown at d, Fig. 4, with which it is weighed ; an exhausted receiver b is also weighed and attached to one end of this tube ; the other is connected with four **U** tubes, two of which are filled with caustic potash and two with sulphuric acid for removing the carbonic acid gas and water. The glass tubing a is raised to red heat, the stop-cocks of the receiver are opened, and a slow current of air passes over the copper ; its oxygen is removed and nitrogen only passes into the empty receiver. The gain in weight of the copper represents the weight of the oxygen, and that of the receiver the weight of nitrogen.

It has already been stated that carbonic acid gas is present in the atmosphere ; the breathing of animals and the burning of carbonaceous bodies are continually supplying this gas ; and although this operation is



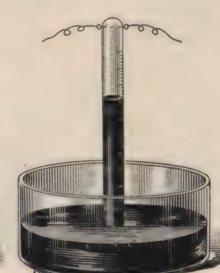


FIG. 2. FIG. 3.

proceeding without intermission, the quantity of carbonic acid gas is practically constant. Its amount varies between 3 and 6 parts in 10,000, according to the locality where, and the time when, the gas is collected. This quantity, small though it may

appear, is of vast importance to the vegetable kingdom, being the source from which all organic carbon in nature is derived. Animals can only assimilate carbon from previously existing organic compounds. Vegetables decompose carbon dioxide, using the carbon in the formation of their tissues and liberating the oxygen in the free state.

The effects, therefore, of animal and vegetable life on the atmosphere are opposite in character: the one removes oxygen and returns carbonic acid gas, the other decomposes this compound and again yields oxygen to the air (this return action is, however, partially balanced by the ordinary process of decay); these two processes going on simultaneously, keep the proportion of carbonic acid gas in the air within certain limits. The decomposition of some rock-forming minerals, as feldspar, by the action of carbonic acid gas, which combines with the bases that they contain, is another important drain on the amount of this gas in the air.

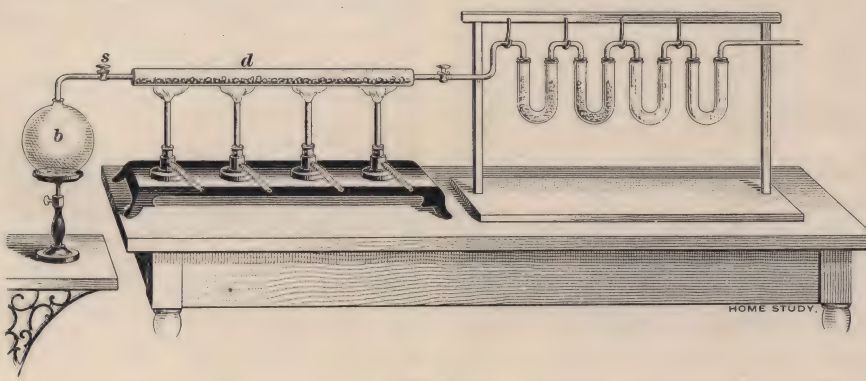


FIG. 4.

The amount of water vapor which the atmosphere contains varies considerably, but there is always more or less of this vapor present. Its presence may be easily demonstrated by bringing a vessel of ice-cold water into a room: the vapor condenses on the outside as a film of moisture.

Ammonia is only found in air in minute traces. These, however, are important, as from them the plants obtain a great proportion of their nitrogen.

Having now satisfied our curiosity in regard to the chemical composition of the atmosphere, an important physical question remains to be settled.

We often hear the question, Why do we not, as dwellers at such an immense depth in the aerial ocean, feel any sense of weight or oppression? It is a well-known fact that in the deepest parts of the Atlantic and Pacific oceans the pressure of the paltry four or five miles of water is sufficient to crush strong-closed vessels of metal or thick glass which may be attached to sounding-lines—a fact which may be easily understood when we stop to think that every fathom, as the mariner says, or in plain English, every six feet of water, means a pressure of about two and one-half pounds on every square inch of surface; so that when thousands of fathoms are in question, the pressure on every square inch runs well up into tons. This being so, it is quite clear that living creatures at such a depth, or even lesser depths, must be so constituted as to be able to stand the pressure upon them; and this they are able to do for the very simple reason that they are filled with fluid already compressed to the same extent as that outside them, and hence not liable to further compression, so that they are quite at their ease despite their enormous burden. Let, however, one of these denizens of the deepest sea yield to the temptation of the plummet, and mistaking it for a dainty morsel, pay the penalty by being hauled up with it to the surface, and what will then happen? Sad to say, long before the surface is reached, the outside pressure being reduced, the compressed fluids inside expand, and bang goes the entire economy of the poor, deluded aspirant to "realms above," where nothing but tatters and fragments arrive, as the result of the explosion.

We deep-sea fish of the aerial ocean find ourselves exactly in the same predicament, under similar conditions. Our bodies are permeated with fluids and gases all compressed to exactly the right degree by the

weight of the air above and around us. Hence, as a general rule, we do not feel any sense of oppression, notwithstanding that every square inch of us bears a weight of nearly fifteen pounds; though, doubtless, our feelings of discomfort under unusual conditions of the barometer may be imputed to this fine adjustment being slightly upset.

Let us, however, try to upset it a little more by chartering a balloon and imitating our hungry and dainty fishy friends. For a few thousand feet we will feel all right enough, and we can regard the prospect below with fair equanimity. Presently, however, our internal adjustment begins to go wrong; we begin, apparently, to swell—not, perhaps, so visibly as Sam Weller's young woman at the tea-meeting—but certainly enough to render us rather uncomfortable, and this swelling sensation goes on increasing the higher we rise, until, unless the balloon-valve is pulled in time, our veins burst their walls.

Between the aerial and the watery ocean there are, however, wide differences of condition, apart from the minor one of density. In the watery ocean it is the surface which forms the chief area of life and tidal activity. The water in the profoundest depth is nearly motionless, is wrapt in absolute darkness (so far, at any rate, as sunlight is concerned), and its temperature, even under the tropic sun, is at or very near freezing-point.

In the aerial ocean, on the other hand, though the greater lightness of air permits its currents to influence it from bottom to top, the chief area of life is at the bottom; light permeates it freely, and while the temperature at the bottom may be high, it is only necessary, even in tropical countries, to ascend a comparatively few thousands of feet to find not merely that the freezing-point is reached, but that the higher we climb the colder it becomes, until, finally, could an unexploded mortal manage to reach its limits, the inconceivable cold of space itself would be encountered. These opposite conditions are both due to one and the same cause. It is the life-giving rays of the sun, which, refusing to part with their heat to the air, and unable to penetrate beyond a short distance into the water, confine their beneficent warmth to the earth's surface as the bottom of the aerial ocean, and the surface of the seas as the uppermost limit of the watery one.

CURRENT TOPICS.

Mrs. F. R. Honey.

THE WAR IN INDIA.—Another war in India! It is barely three years since the last one was fought. Why does the world so frequently hear of war in India? Why are the British there at all? Why should that small island, Great Britain, continually obtrude itself on the public eye, and be involved in disturbances far from her own shores? Such questions are often asked, and the incidents of the present time suggest an answer.

The island of Great Britain is not the British empire. The British empire includes Great Britain, her family, the colonies, and her great dependency, India, to whom she is, on the whole, a kind and careful stepmother. And in such a large family, so widely scattered, with such diverse interests to develop and protect, occasional disturbances must inevitably take place, unless, indeed, the empire becomes a Utopia, and guardian angels descend to be her governors!

And why are the British in India? Americans, with British blood in their veins, with British traditions behind them, and history which bids fair to rival that of Britain before them, recognize the irrepressible power of expansion that belongs to nations of the Anglo-Saxon race, so that wherever on the face of this earth they gain a foothold there they stay and take possession, whether they are Americans subduing and exterminating tribes of Indians, or British establishing their rule over millions of East Indians. That is why the British are in India. And if they were not there what would have happened? It is incredible that in these days a fertile and accessible, but ill-governed, country would have been left to itself, torn by internecine wars, ignorant of the arts by which commerce may be developed and its products made to contribute to the wealth of the world.

There was a time when France, Holland, and Portugal were England's rivals in India. Would the world have been any better off if either of those nations had won the prize?

For good or for ill, however, the British are in India; and before the causes and incidents of the present frontier war are considered, it will be interesting to glance at the history of the conquest and occupation of this Asiatic peninsula.

Not long after Columbus had sailed westward and discovered America, a Portuguese navigator, Vasco da Gama, sailed eastward and discovered the water-route from Europe to India, round the south of Africa. Before his time India could only be reached by a long, dangerous, and difficult land journey. The mountains which divide her from the rest of Asia are quite impassable, except at a very few points on the northwestern frontier; and through these passes, between the territories now known as Afghanistan on the one side, and the Punjab on the other, have poured the armies which in past ages have entered India, and there acquired dominion for their masters. Many such invasions have taken place; for India, from the earliest times down to the days of the Nabobs, who made their fortunes there a few generations ago, has been regarded as a mine of wealth.

The sixteenth century was a great period of maritime adventure, and when once Vasco da Gama had shown the way, the ships of Europe became familiar objects on the shores of India. England, France, Holland, and Portugal made settlements on the coasts, and carried on trade with the natural and manufactured products of the country. None went there with the desire or intention of conquest. The first ships carried no soldiers, but merchants, who had arms sufficient only to defend themselves and their goods, and who expected and desired to sustain friendly relations with the native races. The East India Company of England, which was eventually to obtain control of the country, was formed in 1599 by a few London merchants who objected to the high price which Dutch traders put on Indian pepper, a point about which they certainly did not intend to fight!

If only one nation had settled in India her destiny might have been very different. But during the eighteenth century England and France, who kept well abreast in the race for commercial power in Asia, were frequently at war, and part of their quarrel was fought out in India, with the aid of native troops on both sides. For India is not a single country, inhabited by one race, and speaking one language. It is, like Europe, a vast territory, divided among many governments, with a variety of peoples and of tongues. It was easy for England and for France to secure allies from tribes which were themselves at enmity, and had feuds of their own to settle. The fortune of war, the political conditions at home, and the superior military skill of the English leaders at a critical juncture, combined to decide the contest for supremacy in England's favor. The East India Company, with the protection of trade and commerce as its main object, continued to make treaties with friendly tribes, and to fight those who were unfriendly—always with the aid of native troops—until large sections of the country were under its control.

As long as anything has been known in detail of the history of India, she has been the prey of invading races. The Marathas, who had gained the upper hand in the eighteenth century, were cruel and tyrannical; robbery and violence prevailed and were unpunished, and organized resistance on the part of those whom they oppressed seemed impossible. This state of things could not continue in the presence of a powerful European race whose commerce was liable to injury and even to ruin from these internal troubles, and who had learned by experience that native troops would fight faithfully under foreign commanders when well paid and well led; and after many years of alternate peace and conflict, the East India Company found itself the ruler of the greater part of the country.

It should always be remembered that this conquest was not made by England as a nation; but that a trading company, beginning business in a very small way, by degrees acquired this rich prize, and handed it over to the mother country only when its government became too great a matter for private management. Great Britain, a small island in the North Atlantic, could never have dreamed of conquering India, a vast territory many thousand miles away, had she been opposed by a united people fighting for their fatherland. She has become possessed of this great dependency by other means than by brute force, and by other means she must hold it, if her power is to endure. The means by which she proposes to hold it are the maintenance of *pax Britannica*, "Britain's peace," so that every man's life and property may be safe; the

equal administration of justice, irrespective of color or of race; just taxation, amounting to less than one-half of that which used to be paid to native rulers, and of which every rupee is spent on the defence, the government, and the development of India; the spread of education; the introduction of those products of modern civilization, railroads, telegraphs, canals, and good roads, which may aid in the advancement of the country and of the people. She has made many mistakes, many failures in judgment, many blunders; and the agents of the East India Company in the early days of its power committed some crimes which have been much exaggerated, and have never been forgotten. But some of the best and ablest men of the century have spent their lives in India, working with a single eye to the good of the country, and endeavoring to promote the happiness and welfare of the people among whom their lot was cast.

Since 1858 England has had to solve a problem such as the history of the world has never before presented: the peaceable government of two hundred and twenty-five millions of people, who, in race, in language, in religion, and in customs, differ not only from their rulers, but from one another. She has pledged herself not to interfere with any form of religion, except when actual crime is involved in its practice, such as the burning of widows or the murder of infants; nor with the customs and the caste-rules, which sometimes, as in the case of the recent plague in western India, render the enforcement of sanitary regulations extremely difficult. About one-third of the area of India is still ruled by native chiefs, who reign over their subjects almost as independent sovereigns, and have revenues and armies of their own. They have all, by treaty, acknowleded the British government as the paramount power, and have agreed not to make war upon each other, or to form alliances with foreign countries. At each native court there is a British resident, who, in cases of gross cruelty or misrule, interferes for the protection of the weak and for the maintenance of peace.

The country in which this problem of government is to be dealt with is one which, by its geographical position, is liable to an irregular rainfall, producing uncertain harvests, so that occasional famines in some districts are regarded as inevitable. The greater peace and security of the country under British rule have caused the population to increase with rapidity, and thus the distress arising from plague and famine is great in proportion to the large number of people affected by these calamities.

It may cause surprise that the Hindus submit thus quietly to be governed by an alien race, but it should be remembered that the mass of the people has for many generations been subject to foreign dominion. The sentiment of national independence may, therefore, be said scarcely to exist among them. So long as their persons and their property are protected, and their religion and their customs are respected, they care little who administers the law under which they live. The population includes about sixty millions of Mohammedans, of whom a part are descended from the races that were in power before the English were established in India, and were dispossessed by them. These still retain the memory of their predominance, and are of a more vigorous and combative character than the Hindus. They are less submissive to the restrictions of the British government, and if serious trouble should arise it will probably be caused by this section of the population, rather than by the native races, among whom, however, there are a large number of Mohammedans.

During the last half-century there has been but one outbreak in the country itself, the mutiny of 1857; and terrible as that was, it was confined to one part of India, and mainly to one class of the inhabitants. The other Indian wars that have occurred have been with frontier races, who endangered the peace of the country either by quarrels among themselves or by attacks on the borders of the British dominions. Such a frontier war is the one now in progress in the mountainous region which divides British India from Afghanistan, and from the part of Asia which is recognized as being within the sphere of Russian influence. This war will be the subject of next month's paper. It is more than a mere conflict between semicivilized tribes, who are entrenched in a strong natural position, and a foreign race which is as certain of eventual success as is the army of the United States when war is carried on against the Indians in this country. Its real importance lies in the fact that it is a struggle on the border-line between the two great European powers, Great Britain and Russia, who are now predominant in Asia, and whose relations to one another in that part of the world will probably be one of the main features of the history of the twentieth century.

THE COOKING OF WHOLESOME MEALS.

Mrs. Henry Esmond.

An Inexpensive But Tasty Supper—Useful Hints on Preparing Creamed Potatoes, Baked Apples and Jelly Roll—A Good Cup of Cocoa.

WHAT shall we have for supper? Many a good housewife knits her brows and looks uncommonly serious, trying to decide. She knows that after a hard day's work a man is none too easy to please. Breakfast *never* worries her, dinner seldom, but with supper it is different. Let us see what can be done with the cold roast beef left over from dinner, helped out with sundries.

BILL OF FARE FOR SUPPER.

Roast Beef Cooked with Gravy.
Creamed Potatoes.
Biscuits. Cocoa.
Baked Apples. Jelly Roll.

Roast Beef with Gravy.—Cut in small pieces cold roast beef, removing the fat and any stringy portions. Put the meat into a frying-pan (if there is any of the thick gravy put it in with the meat), add 1 cup of cold water, cover and let it stew for 10 minutes, or until the water is colored with the meat juice. Now add 2 rounded tablespoonfuls of flour moistened with 4 tablespoonfuls of cold water; stir well to prevent lumping. Add a dash of pepper and ¼ teaspoonful of salt. Pour it over small squares of toast which have been moistened with hot water and buttered. Roast lamb may be prepared in the same way. One teaspoonful of Worcestershire sauce or 2 tablespoonfuls of tomato catsup heighten the flavor. This, if desired, can be prepared in the chafing-dish.

Creamed Potatoes.—As the boiling of potatoes has been explained before, it is not necessary to repeat. Cut 6 medium-sized, cold, boiled potatoes into cubes ½ inch square. Put 1 tablespoonful of butter into a saucepan and, when it is melted, add 2 tablespoonfuls of flour; mix well, then add, slowly, 1½ cups of cold milk. The milk should be added a very little at a time, and if it lumps, the pan should be removed from the fire and the contents beaten vigorously. This should be repeated each time the milk is added. When all the milk is in, add ½ teaspoonful of salt and the potatoes; cook for five minutes. Chopped parsley is a very good addition.

Cocoa.—To 3 cups of milk add 1 of water. Let it heat, but not boil. To each cup of liquid use 1 good teaspoonful of cocoa. Mix it to a smooth paste with boiling water. Then add a little of the hot milk. When all the lumps are gone, pour it into the remainder of the milk. Add to this 1 tablespoonful of sugar to each cup of milk. Let it just come to the boiling-point; move the saucepan to the back of the stove and beat the cocoa with the egg-beater. Let it remain on the fire for 10 minutes. Be careful to keep the saucepan covered, otherwise a thick, tough skin will form on the top of the cocoa. The addition of ½ teaspoonful of vanilla is a great improvement.

Biscuits.—To a quart of sifted flour add 1 level teaspoonful of salt and 2 teaspoonfuls of baking powder. Sift into a bowl and add 2 tablespoonfuls of shortening, 1 of lard, and 1 of butter. Rub in quickly with the tips of the fingers. When the shortening is all mixed in, moisten with 1½ cups of sweet milk. More milk may be needed, as the dough should be as soft as possible; the softer the dough, the lighter the biscuits. Turn out onto a well-floured board and pat out lightly with the rolling pin. Cut with a small cutter or an ordinary glass, which has first been dipped in flour. Place close together in a pan and bake in a hot oven 12 or 15 minutes.

Baked Apples.—Core and pare 6 good-sized apples; put them in a pie-pan or a round cake-pan. Put a small piece of butter into the hole in the center of each apple; then fill it up with granulated sugar. Pour ½ cup of boiling water into the pan and bake in a hot oven 25 or 30 minutes. When done, leave in the pan until they are nearly cold, as the apples do not break so easily when cool as when they have just come from the oven.

Jelly Roll.—Beat together 1 cup of granulated sugar and the yolks of 3 eggs, and 2 tablespoonfuls of milk. Sift into this 1 cup of flour, to which has been added 1 teaspoonful of baking powder. Mix the flour in

lightly, then add the whites of the eggs (which have been beaten stiff), and 1 teaspoonful of vanilla. Bake in an oblong pan in a moderately hot oven. Do not let it get too brown. Ring a cloth out of cold water and spread it on the pastry-board. When the cake is done, turn it out onto this cloth. With a sharp knife, that has been dipped into hot water until thoroughly heated, cut the cake into three slices. The reason for using the wet cloth is that it keeps the cake moist and makes it easier to roll. Whenever hot cake or bread is to be cut, use a hot knife, as this keeps the bread from becoming soggy. Spread the cake (one slice at a time) with sour jelly, either currant or grape. Roll up the cake and tie loosely with string, otherwise it will unroll; wrap it up in the damp towel. This keeps it moist.

NOTICES.

IMPORTANT.

THE following information is for the benefit of those who send questions to the Answers to Inquiries Department:

* All letters containing questions should be addressed to the Editor of "HOME STUDY MAGAZINE," Scranton, Pa.; and this address should appear not only on the envelope but also *at the head of the letter itself*.

* Under no conditions will questions be answered by mail.

* If a stamp is enclosed, we will acknowledge the receipt of the inquiry and inform our correspondent in what number the answer may be expected to appear.

* Questions that are for any reason unsuitable for the Answers to Inquiries columns will be promptly returned to the sender.

* Write on one side of the paper only and make drawings for illustrations on *separate* paper. Take pains to make your drawings and sketches as clear as possible.

* For our information, and not for publication, names and addresses must accompany letters or no attention will be paid to them. The full name will not be published under the question asked, but only the initials of the writer's name and the name of the town or city from which the letter is received. If the party asking a question does not wish his initials to appear, he should let us know what letters to use.

* References to former answers should give date of paper and number of question.

* Letters sent to correspondents, under cover to the Editor, will not be forwarded, and the names of correspondents will not be given to inquirers.

* Buyers wishing to purchase any book or other article not advertised in our columns will be furnished with addresses of houses carrying the same.

* Books referred to promptly supplied on receipt of price.

* Minerals sent for examination should be distinctly marked or labeled.

A NEW BOOK.

HOW TO BUILD A HOME—THE HOUSE PRACTICAL. By Francis C. Moore. 12mo, decorated board cover. Published by Doubleday & McClure Co., New York, 1897. Price $1.

In his preface to this book, Mr. Moore informs us that, as an amateur, he made a study of construction for a quarter of a century, and that when he finally came to build a house for himself he submitted his plans to architects, carpenters, masons, and other practical men with whom he enjoyed acquaintance, the result being that he is now able to say, after living in the house, that, if he ever has to build again, he will use the same plans.

In this book we are told in a very agreeable and instructive manner how the House Practical—that is, the durable, healthful, comfortable, convenient, and approximately fire-proof house—may become also the House Beautiful.

A practical example is given, in which are complete plans in detail of a spacious and convenient summer cottage which can be built for a comparatively small sum.

ERRATUM.

January Number.—Article, "Napier," the word *exponents* in the second line should be *logarithms;* the first paragraph then reads:

"The following laws, which govern all operations with logarithms, are easily deduced from the laws of exponents."

ANSWERS TO INQUIRIES

(1) Can you tell me whether lard-oil that has been used can be cleaned and used again? Can you explain the process? G. R., Rockford, Ill.

ANS.—Filters are in use for cleaning and rendering fit for further use such oils as rape, cottonseed, and mineral oils after being used in steam-engines and machinery; we are not informed as to whether the same treatment is suitable for lard-oil.

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(2) (*a*) I have a duplex compound-condensing pump with steam-cylinders 14 inches and 26 inches and water-cylinders 13 inches in diameter, all with a stroke of 18 inches. The pump works against an average water-pressure of 60 pounds per square inch, with an average suction of 3 feet. The steam-pressure at the pump is 35 pounds, at the boiler 80 pounds. What will be the horsepower when the pump makes, respectively, 10, 20, and 40 revolutions per minute? (*b*) With a water-pressure of 100 pounds there is a pressure of 60 pounds in the steam-chest. What is the horsepower for these pressures?
A. W. W., Sterling, Ill.

ANS.—(*a*) Computing the horsepower from the pressure against which the pump works, and allowing 20 per cent. of the total power for frictional losses, the pump requires 18 horsepower to drive it at 10 revolutions per minute, 36 horsepower at 20 revolutions, and 72 horsepower at 40 revolutions. (*b*) Computing the power in the same way as before, the horsepowers will be: for 10 revolutions 30 horsepower, for 20 revolutions 60 horsepower, and for 40 revolutions 120 horsepower.

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(3) What causes butter to stick to some parts of the sides and flail of an oak churn?
C. K. S., Wayland, Iowa.

ANS.—This question does not belong to any branch of engineering. It is rather one that the experienced dairyman should answer for himself. The conditions of the weather and the temperature of the cream no doubt have something to do with it, and so, probably, has the nature and grain of the wood of which the churn is made, but it is impossible for us to give any specific reason.

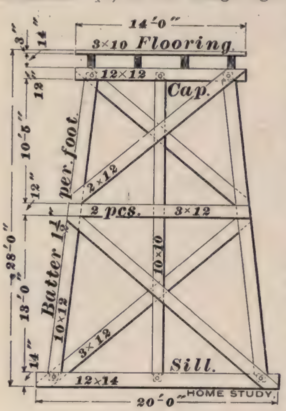
***

(4) (*a*) How can the weight of smoke be ascertained? (*b*) Is it correct to say that the inertia of a locomotive is greater, the higher the boiler is raised from the ground, that is, the larger the wheels are upon which it runs? J. B., Fredericksburg, Va.

ANS.—(*a*) Take a flask of known capacity, exhaust the air from it and then weigh it. Next fill the flask with the smoke to be tested and weigh it again. The difference in the two readings will be the weight of the smoke. (*b*) The inertia of a body, in the general acceptation of the term, depends only on its mass or, popularly speaking, its weight. Raising the boiler of a locomotive does not increase the inertia of the latter. The higher the center of gravity of a body is lifted above the ground, the more effect a given force will have in tending to overturn it, but this is not due to increased inertia. As you seem to imply, the size of driving-wheel is one of the determining factors in the height of a boiler.

(5) We have to erect a trestle from a tipple to a drift-mouth, a distance of 225 feet. The load this trestle will have to sustain consists of a 15-ton motor, 20 loaded cars, 4,500 pounds each, and 20 empty cars, 1,500 pounds each—total, 75 tons. The bents will be 28 feet high for 140 feet from the tipple, and from here the ground gradually rises to the drift. The trestle will be 14 feet wide for a distance of 150 feet from the tipple and 9 feet wide for the remaining 75 feet. The timber to be used is well-seasoned white oak. Please answer the following questions. (*a*) How far apart should the bents be placed? (*b*) What should be the sizes of the timbers used in this trestle? (*c*) Is there any rule for calculating the lengths of sill and cap for a given height of trestle? If so, please give such rule. (*d*) What is the best timber to use in such a structure? E. S., Sherodsville, Ohio.

ANS.—(*a*) It is customary in designing such a trestle to place the bents 12, 14, or 16 feet apart, center to center, according to the surface conditions and the length of timber that can be most readily obtained. (*b*) In the designing of trestles, the load, the width of the trestle-floor, and its height above the ground are all the factors the engineer works from. The usual batter given to the outer legs is $1\frac{1}{2}$ inches per foot of vertical height. The legs are boxed or gained $\frac{1}{2}$ inch into the cap and sill, besides being mortised and pinned at each end. The bents are sway-braced as shown in the accompanying illustration. Longitudinal bracing is also used to tie the bents together.



We have marked upon the sketch the proper sizes of all the bent timbers, in the case cited; also the sizes of stringers for a span of 16 feet, center to center. The stringers should be so laid as to be under the rails, butting against each other, end to end, and tied together by splice pieces. (*c*) There is no fixed rule for calculating the lengths of caps and sills, but it is usual to make the length of the cap equal to the width of the platform; then add to the length of the cap $\frac{1}{4}$ of the vertical height between the cap and sill, for the length of the sill. (*d*) It is best in this case to use oak for the flooring and stringers, and white pine for the remainder.

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(6) In order to fill a locomotive-boiler preparatory to firing up, we placed another locomotive with a full tank of water and a full head of steam (140 pounds) on an adjacent track. This locomotive was equipped with a No. 10 Nathan Monitor injector,

NOTE.—For conditions to be observed by subscribers wishing to have questions answered in this department, see notice on opposite page.

the branch-pipe of which we connected to the "dead" engine, the pop-valve on which was set to blow off at 190 pounds. When the boiler of the "dead" engine was partly filled, this pop-valve blew off and the steam gauge registered 190 pounds. Please explain how it is that with but 140 pounds pressure supplied to the injector, a pressure of 190 pounds can be produced. M. A. K., Mauch Chunk, Pa.

ANS.—As the empty boiler was filled, the air in it was compressed until the pressure reached the blowing-off point, 190 pounds per square inch. To reach this pressure, the air must have been compressed to $\frac{1}{13}$ of its original volume, that is, the boiler must have been $\frac{12}{13}$ full of water. There should be no trouble in forcing water into a boiler against a pressure of 190 pounds if the steam-pressure is 140 pounds. The ordinary exhaust-steam injector is fed with steam at about 17 pounds pressure and can force water into a boiler against 80 pounds pressure. The work required to force the water against the excess of the pressure is supplied by the heat of the entering steam, and is in any case only a small fraction of the total heat that might be supplied by the steam.

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(7) I have a 2-horsepower gasoline-engine and would like to know if you will furnish me with plans and description of a suitable carbureter for use with same. S. G. M., Montclair, Col.

ANS.—A carbureter, or mixing valve, is illustrated and described in the article "Gas-Engines" in this month's (February) issue of HOME STUDY MAGAZINE. As this is a patented device, you will have to obtain permission for its use of the manufacturers, The Sintz Gas-Engine Company, Grand Rapids, Mich.

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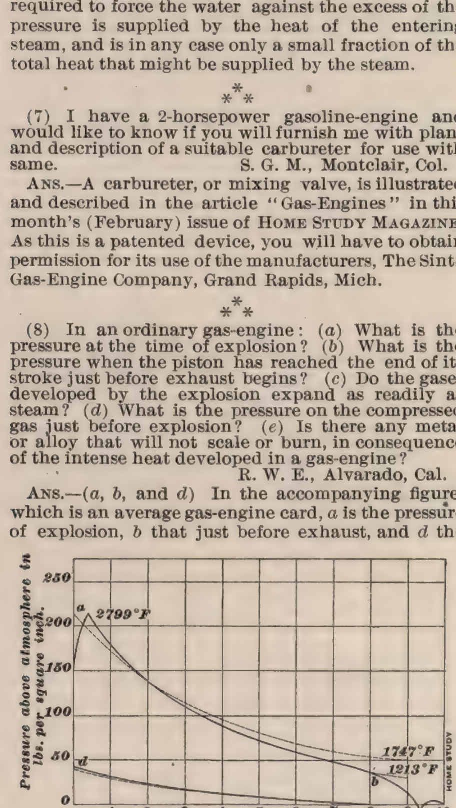
(8) In an ordinary gas-engine: (*a*) What is the pressure at the time of explosion? (*b*) What is the pressure when the piston has reached the end of its stroke just before exhaust begins? (*c*) Do the gases developed by the explosion expand as readily as steam? (*d*) What is the pressure on the compressed gas just before explosion? (*e*) Is there any metal or alloy that will not scale or burn, in consequence of the intense heat developed in a gas-engine? R. W. E., Alvarado, Cal.

ANS.—(*a*, *b*, and *d*) In the accompanying figure, which is an average gas-engine card, *a* is the pressure of explosion, *b* that just before exhaust, and *d* the



PARTS OF THE STROKE.

pressure after compression. (*c*) Yes. (*e*) We know of no such metal. Gas-engine cylinders are usually surrounded by a water-jacket to prevent overheating. In HOME STUDY MAGAZINE there is now appearing a series of articles on gas-engines. This series commenced in the December number, 1897.

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(9) (*a*) I am anxious to construct a furnace from which, by the combustion of Connellsville coke, a full equivalent of carbon dioxide gas can be obtained; can you tell me of any text-book or authorities on the subject? (*b*) If I take an ordinary heating stove, is it necessary to admit air *over* the burning coke, or will sufficient oxygen be admitted if the draft underneath the grate is open? (*c*) How can I be sure that enough oxygen is being furnished to make carbon dioxide instead of carbon monoxide? (*d*) How can I adequately purify the gas? (*e*) What pumping force is necessary to remove gas to a receiver as fast as it is generated, assuming 100 pounds of coke as a charge? E. H. A., Mount Vernon, N. Y.

ANS.—(*a*) "Fuel, Its Combustion and Economy," by D. K. Clark, will give you a great deal of information on this subject. (*b*) If the bed of fuel on the grate is not too thick it will not be necessary to admit air over the burning coke. (*c*) It will be necessary to have the gases analyzed. (*d*) The dust and some of the sulphur can be removed from the gas by washing. It will be impossible to separate the carbon dioxide from the nitrogen and other gaseous products of combustion by any simple process. (*e*) This question is too indefinite for us to give a complete answer. The pumping force will depend on the rate at which the gas is produced and the pressure in the receiver.

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(10) (*a*) What will be the effect on boiler-sheets and tubes if the feed-water is strained through bituminous coal? (*b*) Will steam-pipes give out any more heat if the pressure of the steam in them is increased? W. H., Williamstown, Mass.

ANS.—(*a*) Most bituminous coal contains sulphur, which would be absorbed by the feed-water and corrode the sheets and tubes. (*b*) Yes. The temperature of the steam in the pipes increases with the increase in pressure, and the amount of heat given off by a hot body increases with an increase of temperature.

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(11) The article in HOME STUDY MAGAZINE entitled "Wonders of Pressure, Heat, and Cold" is of great interest to me, and must be of value to many. There are some points I do not understand and would be glad if you will explain them. You say that a column of air reaching 5 miles below the level of the sea produces, by its own weight, sufficient heat to melt steel. In trying to verify this from other information you give in the article, I cannot get such a heat. Please explain. C. A. J., Everitt, Mass.

ANS.—As the pressure of air, in common with other gases, varies directly as the weights of equal volumes, then, when the density of air becomes such that a cubic foot weighs 62.5 pounds instead of .0766 of a pound at atmospheric pressure, the pressure must be equal to $\frac{62.5}{.0766} = 816$, nearly; that is, it requires a pressure of 816 atmospheres to compress air at 62° F. to a density equal to that of water. As the temperature of air increases as its volume reduces, the increase of temperature, due to 816 cubic feet of air being compressed into the volume of 1 cubic foot, can be found, and the following formula can be used to determine it.

Let n = number of atmospheres;
14.7 = atmospheric pressure in pounds per square inch;
and T = temperature after compression.

Then
$$T = \left(\frac{81\,n}{\sqrt[5]{n}}\right) + 62.$$

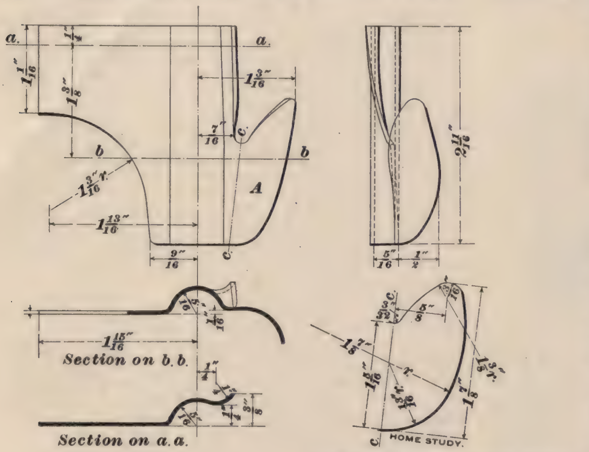
Applying the formula, therefore, to the case before us, we have
$$T = \left(\frac{81 \times 816}{\sqrt[5]{816}}\right) + 62 = 17{,}353.67° \text{ F.}$$

As the average melting temperature of steel is equal to 2,600° F., it follows that $\frac{17{,}353.67}{2{,}600} = 6.674$; that is, the temperature due to compression is 6.674 times greater than that required to melt steel. But, as the excessive temperature of compression would reduce the density of the air, and as much of this

heat would be absorbed by the encasing rocks, it was not claimed that more heat would be retained than would melt steel.

* * *

(12) I have sent you a small forging of which I am unable to make a working-drawing. May I ask you to do this for me, and to return the forging to my address? E. M. R., Dayton, Ohio.



Section on b.b.

Section on a.a.

Development of A from line c.c.

ANS.—The above is a working drawing of the piece you sent us, with all necessary dimensions marked thereon.

* * *

(13) Referring to the article "The Prony Brake," which appeared in HOME STUDY MAGAZINE for July, 1897, I would like to know how much pressure (which from your illustration is regulated by thumb-screws, and, therefore, cannot be great) should be applied to the parts that embrace the pulley also. What would be the effect of increasing or decreasing that pressure? M. E. O'C., Porter's Mills, Wis.

ANS.—The pressure applied by means of the thumb-screws is regulated by trial, the idea being to keep the pressure just sufficient to give the normal load at the given speed. Supposing the brake to be applied to an engine fly-wheel, if the pressure is increased, the load is increased in proportion, and the engine will slow down. If the pressure is decreased, the effect is to diminish the load on the engine, in which case it will run faster unless restrained by the governor.

* * *

(14) (*a*) What is the best way to prevent steel from rusting? (*b*) What is the best way to remove rust from steel? (*c*) How can I remove ink stains from paper? J. R. B., Fredericksburg, Va.

ANS.—(*a*) We do not know the *best* way. A *good* plan, however, is to apply to the surface a mixture of tallow or lard and thick white-lead paint. (*b*) To remove rust from steel, immerse the article to be cleaned for a few minutes in a strong solution of cyanide of potassium, say in the proportion of about ½ ounce in a wine-glassful of water; take out and clean with a brush, using a paste composed of cyanide of potassium, castile soap, whitening, and water; these last are mixed in a paste about the consistency of thick cream. (*c*) Mix oxalic acid and tartaric acid in powder. Dissolve a little in water and apply to the ink stains. The preparation is poisonous.

* * *

(15) Our water supply is obtained from four bored wells of 8-inch diameter and 50 feet deep. Each well is supplied with a 15-foot strainer, which lies in a gravel stratum. The tops of the wells are plugged and the pump with its suction-pipe is tapped into the well-pipes 12 feet below the top of the wells. The water is pumped 7 miles against a head of 300 feet. Now, the water contains too much iron, and after standing a few hours a red substance settles in it. (*a*) Is it the iron that settles in this way? (*b*) Is it expensive to filter water, as laundry companies do, by pumping it through a cylindrical vessel in which are chemicals for purifying it? (*c*) Our pump has a maximum pumping capacity of 1,200 barrels per hour; how would you advise us to get rid of the red substance? Of course we want to do it with as little expense as possible. (*d*) What kind of filtering process would rid the water of *all* its impurities? J. H. Mc., Richmond, Mo.

ANS.—(*a*) It is impossible to tell you with certainty whether the red sediment is iron or not, without testing it. However, we believe that the water passes through a stratum of ferrous clay and carries with it these ferrous impurities partly dissolved, which, when the water stands for some time, settle down to the bottom of the vessel. (*b*) The expenses are slight, after either a large filter is purchased or the basin excavated. (*c*) There are two ways to get rid of these impurities: (1) To run it through a filter containing charcoal. (2) To collect the water in a large basin, similar to those used for purifying the water supply of cities, that is, in an excavation in the ground with a bed of gravel about 2 or 3 feet deep. The exit of the water must be so arranged that the water always retains a certain level. (*d*) There is no filtration process to remove *all* impurities of water; to obtain chemically pure water it has to undergo distillation. Filtration through charcoal, however, is, for general purposes, quite sufficient.

* * *

(16) (*a*) What is the cause of the most disastrous boiler explosions? (*b*) How much water will one pound of good coal evaporate in a correctly designed and skilfully fired boiler? L. A. D., Brighton, Ill.

ANS.—(*a*) Boiler explosions are caused by overpressure of steam. Either the boiler is too weak to stand the ordinary working-pressure, or the pressure rises to a dangerous point on account of a defective or inoperative safety-valve. The most disastrous explosions occur when a new and strong boiler is ruptured by a pressure far above the working-pressure, and when the boiler contains a large body of water. A boiler which contains a small quantity of water rarely produces a very disastrous explosion. (*b*) From 9½ to 11 pounds from and at 212°.

* * *

(17) Which is the more economical for feeding a boiler—the steam-pump or the injector? L. R. B. R., East Plymouth, Ohio.

ANS.—The injector is always more economical as a boiler-feeder than the steam-pump. Sometimes, for practical reasons or as a matter of convenience, it is advisable to use a pump for feeding a battery of boilers, the question of economy being a secondary consideration.

* * *

(18) (*a*) Is a boiler strained as much by a cold-water pressure of 150 pounds per square inch as by a steam-pressure of the same amount? (*b*) How can I calculate the stresses under the two conditions? A. P. A., Fairmont, Minn.

ANS.—(*a*) The cold-water pressure strains the boiler as much as the steam-pressure. However, the worst stresses to which the boiler is subjected are

due to unequal expansion and contraction, and these stresses are not set up when the boiler is subjected to water-pressure. Consequently, the fact that a boiler safely withstands a water-pressure of 150 pounds per square inch does not necessarily prove that it will safely withstand an equal steam-pressure. (*b*) The stress in the shell-plate of a cylindrical boiler is given by the formula, $S = \frac{pd}{2t}$

where p = pressure;
d = diameter of shell;
t = the thickness of plate,

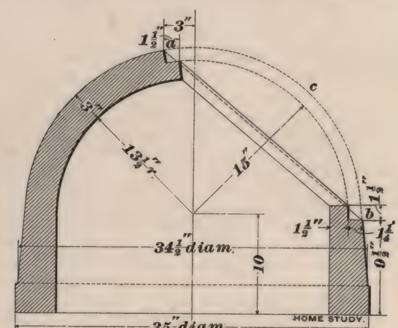
all dimensions being in inches.

For example, if the pressure is 150 pounds per square inch, the diameter, 60 inches, and the thickness, $\frac{3}{8}$ inch, the stress in the plate is $\frac{150 \times 50}{2 \times \frac{3}{8}} = 10{,}000$ pounds per square inch.

* * *

(19) I wish to fit a circular door $1\frac{1}{4}$ inches thick into a hole in the casting shown. How can I make a lay-out of the hole in the casting so that a circular door will fit it accurately? L. P. M., Philadelphia, Pa.

ANS.—Your inquiry is rather vague, as it leaves us in doubt as to whether you have made the door and wish to cut a hole in the cast-iron dome to fit it, or *vice versa*. We presume, however, that the hole was *cast* in the dome, and that you wish to make a cast-iron door to fit it. If this is so, make a full-size drawing like the accompanying figure, and measure all dimensions and angles from it, not forgetting to allow for shrinkage when making



the pattern. In order that the door shall fit the hole accurately, the hole must be machine-finished and the door turned up on the edge. We have supposed that the dome is a half sphere.

* * *

(20) In the enclosed sketch, $AB = 800$, $AC = 600$, and $BC = 400$. How can PA be found? A. W. B., Miles Grove, Pa.

ANS.—If A, X, and B, Fig. 1, are three collinear points, and Q any fourth point, we have the following fundamental and very important trigonometrical relations:

$$XB \cot A - AX \cot B = + AB \cot n. \quad (1)$$
$$XB \cot l - AX \cot m = - AB \cot n. \quad (2)$$

For,

$$QX = \frac{AX \sin A}{\sin m} = \frac{AX \sin A}{\sin (n - A)} = \frac{AX}{\sin n \cot A - \cos n}$$

And

$$QX = \frac{XB \sin B}{\sin l} = \frac{XB \sin B}{\sin (n + B)} = \frac{XB}{\sin n \cot B + \cos n}$$

Therefore,

$$\frac{AX}{\sin n \cot A - \cos n} = \frac{XB}{\sin n \cot B + \cos n}$$

Hence, formula (1) is obtained by an easy transformation. Again:

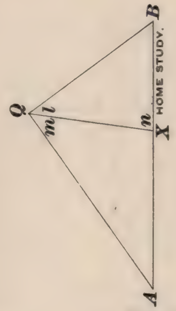


FIG. 1.

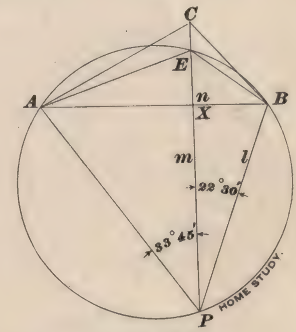


FIG. 2.

$$QX = \frac{XB \sin B}{\sin l} = \frac{XB \sin (n + l)}{\sin l} =$$
$$XB(\sin n \cot l + \cos n),$$

and, $$QX = \frac{AX \sin A}{\sin m} = \frac{AX \sin (n - m)}{\sin m} =$$
$$AX(\sin n \cot m - \cos n).$$

Equating these values of QX and transposing, we get formula (2). Apply formula (1) to the triangle ABC, and formula (2) to the triangle ABP in Fig. 2. Then, by addition,

$$XB(\cot A + \cot l) = AX(\cot B + \cot m),$$

and $$AX + XB = AB.$$

Whence, $$AX = \frac{AB(\cot A + \cot l)}{\cot A + \cot B + \cot l + \cot m},$$

and, $$XB = \frac{AB(\cot B + \cot m)}{\cos A + \cot B + \cot l + \cot m}$$

Substituting in (1), we get,

$$\cot n = \frac{\cot A \cot m - \cot B \cot l}{\cot A + \cot B + \cot l + \cot m}$$

Therefore,

$$\sin n = \frac{\cot A + \cot B + \cot l + \cot m}{\sqrt{(\cot A + \cot B + \cot l + \cot m)^2 + (\cot A \cot m - \cot B \cot l)^2}}$$

From the triangle AXP we have,

$$AP = \frac{AX \sin n}{\sin m} =$$
$$\frac{AB(\cot A + \cot l)}{\sin m \sqrt{(\cot A + \cot B + \cot l + \cot m)^2 + (\cot A \cot m - \cot B \cot l)^2}}$$

which gives $AP = 910.28$.

* * *

(21) How can I make application for a patent direct to the patent office without employing a patent attorney? J. S. McC., Vincennes, Ind.

ANS.—Write to the Commissioner of Patents, Washington, D. C., for the necessary instructions for making an application for a patent. These instructions will be sent free of charge. Read the instructions carefully and follow them to the letter.

* * *

(22) I am thinking of building a flat-bottomed boat large enough to carry 1,000 pounds of oil to be used on the Yukon River in Alaska. (*a*) What would be the approximate horsepower of a steam-engine for such a boat? (*b*) What size boiler would you advise me to use? W. R. M., Nantucket, Mass.

ANS.—(*a*) A 10-horsepower engine will probably give good results. (*b*) A boiler that will furnish enough steam to run the 10-horsepower engine. Its size will depend on its type, the type of engine you use, and the kind of fuel.

(23) One of my customers has 13 flat steam-coils; 8 of these consist of 25 one-inch pipes 12 feet long connected by close return bends, and the other 5 consist of 23 one-inch pipes 6 feet long similarly connected. They are built one above the other and rest upon inclined supports so that each coil pitches toward its discharge. The top coil is fed by steam at 90 pounds pressure, and each coil discharges into the one immediately below it, a continuous run of pipe being thus formed. After turning on the steam it takes two hours for water to appear at the discharge-end of the 3,100 feet of pipe composing the coils. There is *no* discharge of steam, and the flow of water is extremely sluggish. (*a*) Why does it take so long for water to appear, and why is not the discharge of water immediately followed by an escape of steam at considerable pressure? (*b*) In such an arrangement how can I estimate the loss of pressure due to the friction of the steam in the pipes? (*c*) Is it good practice to feed boilers with water from a hot-well into which a Knowles jet-condenser discharges? (*d*) Should the water-level in Cahall upright boilers fluctuate rapidly, showing a variation of 8 inches in the gauge-glasses? The boilers are at a street-railway station. Is it possible that the slight quantity of oil in the hot-well is the cause of the fluctuation?

C. V. C., Boston, Mass.

ANS. (*a*) There must be an obstruction in the pipes. If they were clear, the steam would blow through them very quickly. (*b*) If we denote the absolute pressure of the steam as it enters the pipe by p_1, the pressure as it leaves the pipe by p_2, the quantity of steam that flows through the pipe in cubic feet per minute by Q, the weight of a cubic foot of steam at the pressure p_1 by w, the length of the pipe in feet by L, and the diameter of the pipe in inches by d, the loss of pressure can be found approximately by the formula

$$p_2 = p_1 - \frac{Q^2 wL}{c^2 d^5},$$

where c depends on the diameter of the pipe and may be given the following values for pipes from ½ inch to 6 inches in diameter:

Diam. (inches)	½	1	2	3	4	5	6
Values of c	36.8	45.3	52.7	56.1	57.8	58.4	59.5

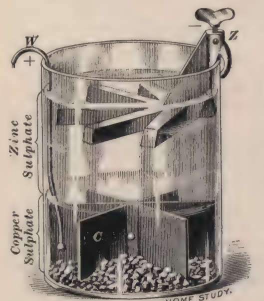
The extra loss due to the effect of bends may be included in the above formula by considering each right-angled bend as increasing the length of the pipe an amount equal to 40 times its diameter. (*c*) Yes. If the hot-well is large and the feed is taken from a point some distance below the surface of the water in the well, there should be no trouble from the little oil that enters the boilers. (*d*) It is possible that the fluctuation is due to priming caused by the action of the cylinder-oil; it is more probable, however, that the trouble is caused by the sudden changes in the demand for steam, due to sudden changes in the load on the engines. When the load is suddenly increased and more steam is used, the pressure in the boiler is reduced and steam is formed rapidly in the tubes. This steam in rising through the tubes lifts the water with it and causes the fluctuation in water-level at the gauge-glass.

***

(24) (*a*) Will you inform me if the enclosed diagram shows the correct way of connecting up 3-candle-power lamps? (*b*) How can I make a blue vitriol battery? (*c*) Which is the positive and which is the negative wire or brush on a dynamo? (*d*) Which is the positive and which is the negative terminal of a cell? (*e*) How many volts does it take to make a horsepower? (*f*) What kind of a fuse cut-out shall I use to protect a 3-candle-power lamp, and (*g*) where shall I put them in the circuit? (*h*) Where can I get them? (*i*) Which is the north and which is the south pole of a battery?

T. W. C., Newmarket, N. H.

ANS.—(*a*) Your diagrams are correct. The number of cells will depend upon the voltage of the lamps you use and the number of volts each cell can furnish. A gravity-cell gives a little over one volt. (*b*) The elements of a blue vitriol or gravity-battery are copper and zinc, respectively, and are generally made as shown in the illustration. The copper element is at the bottom of the cell and is of such a form as to present a large surface. An insulated wire is connected to the copper and is brought to the top as the positive terminal of the battery. A zinc casting, or crowfoot, is hung on the rim of the jar, and is the negative element. To prepare the solution, pour in clean soft water till the zinc, or upper element, is covered, then drop in 32 ounces of blue vitriol, in small pieces. The action of the battery may be hastened by dissolving 2 or 3 ounces of white vitriol in the same weight of water and carefully pouring it on top of the copper solution. The cell should be short-circuited a few hours before being used.



(*c*) The positive (+) brush is that one from which the current is supposed to flow from the dynamo to the outside circuit, and the negative (−) brush is the one which is supposed to receive the returning current. Either can be determined by tracing to the voltmeter, by pole-finding paper, or by a magnet-needle. (*d*) The polarities of the elements of a cell have the same properties as the brushes of a dynamo and can be similarly determined. In a gravity-cell the copper is positive (+) and the zinc is negative (−). (*e*) The *volt* is not a measure of *power*, but of *pressure*. There can be no horsepower in a quantity of water unless the water is flowing. There can be no power in an electric conductor unless the current is flowing. The rate of flow of the electric current is measured in *amperes*. *Ampere* × *volt* = 1 *watt* = $\frac{1}{746}$ *horsepower*. (*f*, *g*, *h*) Cut-out No. 8,300, General Electric Co. Use ½-ampere fuse. It can be inserted near the battery. (*i*) North and south pole refer to magnetic properties.

***

(25) How should gravity-cells be connected for charging storage-cells? How many gravity-cells (plates 6″x 8″) are required to charge four 100-ampere-hour storage-cells? E. Y. W., Bloomington, Ill.

ANS.—You will find this a very expensive operation. We can hardly see the advantage of using secondary batteries in conjunction with primary, as the current can be obtained directly from the primary—not to mention the inefficiency of the method—unless you wish to use the battery for portable services. To charge the four 100-ampere-hour cells would require 120 gravity-cells. They should be so connected up that there will be 12 rows and 10 cells in series in each row. These will be practically exhausted after one charging of the four storage-cells. The same number of Edison-Lalande cells would furnish nine or ten charges.

***

(26) (*a*) Why are fuse-wires numbered so much lower than the actual number of amperes of current necessary to blow them? For example, a fuse-wire that will blow at 24 amperes is styled an 8-ampere fuse by the manufacturers. (*b*) What is the best way to re-fuse a transformer on a live circuit? (*c*) In the circular type of rheostat, at which contact is the

greatest resistance, or must that be found out by experiment? (*d*) For how long a time would an alternating-current dynamo continue to generate electricity if the separate excitation were suddenly removed? (*e*) Of what substance is the resistance composed that is used in connection with the controlling magnets of the Thompson-Houston arc-machine? (*f*) What type of lightning-arresters are generally used on incandescent circuits? A SUBSCRIBER.

ANS.—(*a*) The ordinary carrying capacity of a fuse-wire is commonly understood to be somewhat above the capacity marked. A fuse-wire must be heated up in order to melt. Consequently, it may carry two or three times its ordinary capacity for a few seconds before it is heated sufficiently to fuse it. An 8-ampere fuse should safely carry 9 or 10 amperes for any length of time without blowing. The exact behavior of a given fuse depends on many things, such as the condition of terminals, distance between terminals, material of base, etc., but chiefly upon exposure to the influence of the air. If a fuse is enclosed so that the heat developed in the wire is carried away very slowly, the fuse will burn out at slightly above its rated capacity; but if the fuse is exposed to a cooling blast of air its maximum capacity will be much higher. (*b*) *No work should be done on a live high-tension alternating-current circuit without rubber gloves.* Most transformers are now made with removable fuse-blocks, which may be removed and fused and then replaced in the transformer. Sometimes the fuse cut-out is separate from the transformer and can be cut off from the main circuit with a switch. (*c*) Turning the handle in a clockwise direction cuts in resistance, and the reverse cuts it out. This fact can be learned by inspecting the connections, and also by observing the effect produced by turning the arm. If the rheostat is in the field-circuit of a dynamo, and the voltage of a machine is lowered by turning the handle in a clockwise direction, then as the voltage of the machine is lowered on account of the decreased field-current, it follows that more resistance has been introduced into the field-circuit by this motion. (*d*) For a few seconds. (*e*) Carbon. (*f*) There are nearly as many styles of lightning-arresters as there are electric manufacturing companies, but many of them are of the magnetic blow-out type. The Westinghouse Company manufacture the Wurts "non-arcing metal" lightning-arresters.

***

(27) Please give me rules for solving the following problems relating to naval architecture, viz: How to find (*a*) the center of gravity of a vessel, (*b*) its displacement, and (*c*) the center of gravity of its displacement when afloat.

B. W. R., Oakland, Cal.

ANS.—(*a*) In order to determine the center of gravity of a vessel, its form, the weight of every part, and the weight, form, and position of every portion of the load must be known. When these are all known, the center of gravity of the loaded vessel may be found in the same manner as for any system of bodies. (*b*) The volume of displacement, in cubic feet, may be found by dividing the total weight of the vessel and its load by the weight of one cubic foot of water, which is commonly taken at 62.5 pounds. (*c*) If the form of the hull is known, the submergence, or draft, can be estimated from the volume of the displacement, and, the form of the submerged portion being known, the center of gravity of the displacement may be computed in the same manner as for any irregular homogeneous body. For an elementary article explaining a method for finding the center of gravity of a plane section, see HOME STUDY MAGAZINE, July, 1897. The center of gravity of any transverse or longitudinal section of the displacement may be found by this method, and the method may be applied to finding the center of gravity of any system of bodies, by first finding the center of gravity and weight of each body.

***

(28) I have one 80-volt lamp taking 0.8 ampere, connected up as shown by the full lines in Fig. 1, *p* and *n* being the mains, *j* a junction-box, and *s z* being the branch-circuit to the lamp *l*. I wish to know how to wire up another lamp *t* in the next room, so that it will light up when the first lamp *l* burns out, or either one of the fuses *s* or *z* blow; but I do not wish the lamp *t* to burn when the lamp *l* is all right. The wires should all be lead from the junction-box *j*, which is water-tight. R. C., Eastport, Md.

ANS.—The object may be accomplished by putting an electro-magnet *m*, as shown in Fig. 1, in circuit

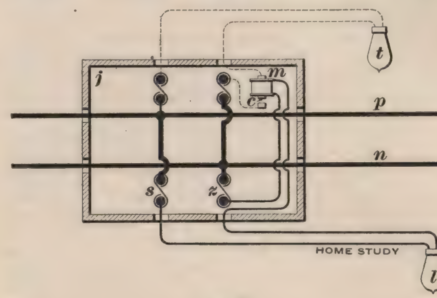


FIG. 1.

with the lamp *l*, whose behavior is to be indicated. The core *c* of the magnet *m* is in the circuit of the telltale lamp *t*. When current passes through the lamp *l*, the electro-magnet *m* is energized, the core *c* is lifted and no current passes through the lamp *t*. But if a fuse *s* or *z* should blow, or the lamp *l* should burn out, so that current ceases to pass through the lamp-circuit, then the magnet *m* would lose its lifting power and the core *c* would drop, thus completing the circuit through the lamp *t*. The magnet *m*

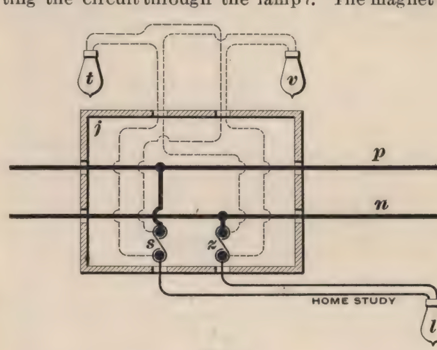


FIG. 2.

need not be in the junction-box, and a bell, operated by a battery, may be substituted for the lamp *t*. Probably a more satisfactory way would be to connect up two telltale lamps *t* and *v* as shown in Fig. 2, which will indicate the blowing of a fuse and the one which has blown, but will not indicate the burning-out of lamp *l*. The action is as follows: When the fuse *s* is all right the fuse-terminals have practically the same potential, and no appreciable amount of current flows through the lamp *t*; but if the fuse *s* blows, then the circuit is still complete through the fuse *z*, the lamp *l* and the lamp *t*, so that both lamps *t* and *l* will illuminate, but with somewhat less than one-half their normal brilliancy.

(29) I have a wire gauge, which consists of an arm swinging about the center of an iron disk, whose outer edge is spiral-shaped. The outer end of the arm is hook-shaped, and the wire is measured by being placed between the hook and the edge; then the arm is swung around until the wire is held tight. The size of the wire is then read off on one side of the disk. On the arm on the other side is found the following: "$\frac{V}{C \times D}$ = ohms per foot." (*a*) Where does this formula come from, and (*b*) how is it used?

A. E. E., Pittsburg, Pa.

ANS.—The formula, or rule, is derived from Ohm's law in a very simple manner. Ohm's law reads:

current = *voltage* ÷ *resistance*.

According to rules in arithmetic, we may multiply both sides of the equation by the same number. Multiplying by "resistance" we have:

current × *resistance* = *voltage*.

Likewise, dividing both sides by "current,"

resistance = *voltage* ÷ *current*.

Now, resistance is measured in *ohms*, and the resistance of a thousand feet, say, of a certain wire is the resistance of 1 foot multiplied by 1,000, or the ohms per foot multiplied by the distance in feet through which the current travels. The rule, then, reads:

ohms per feet × *distance in feet* = *voltage* ÷ *current*.

But we must get *distance in feet* to the other side of the equation. Then, *ohms per foot* =

voltage ÷ (*current in amperes* × *distance in feet*).

The "voltage" is the pressure exerted between the ends of the wire under consideration, and not between the mains or generator-terminals, as might be supposed. This difference of pressure between the ends of the conductor, or voltage, is commonly called the "drop." (*b*) Suppose that a dynamo runs at 120 volts, and we wish to furnish current to 110-volt lamps 500 feet from the station; how many lamps will a No. 0 B. & S. copper wire carry? The total distance traveled by the current is 1,000 feet. The drop is 10 volts. According to our gauge, or any wiring-table, the resistance per foot of No. 0 copper wire is .000098 ohms. Putting these values in the rule above found, we have

$$\frac{98 \text{ ohms per foot}}{1{,}000{,}000} = \frac{10 \text{ volts drop}}{\textit{current} \times 1{,}000 \text{ feet.}}$$

Transposing,

$$\textit{current} = \frac{1{,}000{,}000}{98 \text{ ohms per ft.}} \times \frac{10 \text{ volts drop}}{1{,}000 \text{ ft.}} = 102 \text{ amp.}$$

Each 110-volt lamp takes .6 ampere, nearly. So

number of lamps = 102 amperes ÷ .6 = 170.

***

(30) Can soot from bituminous coal be removed from boiler-tubes by chemical means, say by the use of zinc oxide? H. B. Y., Philadelphia, Pa.

ANS.—We know of no other way to clean tubes than by sweeping by hand or by using a steam-jet. It is very doubtful if the use of zinc oxide, or any other chemical process, would have any beneficial effect in removing the soot from the tubes.

***

(31) (*a*) Can you tell me a quick and efficient way to demagnetize the core of a telegraph-sounder? (*b*) What is the cause of the kicking of the sounder, when the circuit is closed? (*c*) Can the smoke or steam from a locomotive cause a cross or leakage between bare wires? J. H. P., New York, N. Y.

ANS.—(*a*) Iron or steel can be demagnetized by heating to a dull red and then permitting the heat to die out slowly. (*b*) If the sounder is on the local circuit, its "kicking" is a result of the local current being acted upon by the relay, and the trouble is probably on the line; but this you can easily learn by ascertaining whether the sounder responds immediately to the movement of the relay. If the trouble is on the line, whether the sounder is in the main circuit or not, the kicking may be caused by an intermittent short circuit or ground. Perhaps the vibrations of a passing locomotive swing a broken leak-wire into an electrical contact with your line. (*c*) Yes; both carbon and water are good conductors for such small currents, when deposited as a film over the insulators, pins, and arms, but their vapor will probably not affect your line.

***

(32) Can you give me a copy of the Continental Code used on Atlantic cables?

J. H. P., New York, N. Y.

ANS.—

A, - —	N, — -
B, — - - -	O, — — —
C, — - — -	P, - — — -
D, — - -	Q, — — - —
E, -	R, - — -
F, - - — -	S, - - -
G, — — -	T, —
H, - - - -	U, - - —
I, - -	V, - - - —
J, - — — —	W, - — —
K, — - —	X, — - - —
L, - — - -	Y, — - — —
M, — —	Z, — — - -
1, - — — — —	6, — - - - -
2, - - — — —	7, — — - - -
3, - - - — —	8, — — — - -
4, - - - - —	9, — — — — -
5, - - - - -	0, — — — — —

Period, - - - - - -
Comma, - — - — - —
Interrogation, - - — — - -
Exclamation, — — - - — —
Apostrophe, - — — — — -
Hyphen, — - - - - —
Parenthesis, — - — — - —
Quotation, - — - - —
Paragraph, - — - — - -
Understand, - - - — -
Wait, - — - - -
I don't understand, - - — — - - - - - — — - -
Cleared out all right, - — - - — - - — -
Erase, - - - - - - - - -
Call signal, — - — - — - —
End of message, - — - — - — -

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(33) Can you give me any information as to whether there is manufactured a practical automatic battery cut-out used on a gas-lighting system to protect the battery in case of a short circuit or ground?

E. B., Worcester, Mass.

ANS.—Address Weston Electric Co., New York. If the wiring is carefully put up no trouble will be experienced from grounds or short circuits. They can be easily tested for with a cheap detector galvanometer.

***

(34) (*a*) Would you kindly advise me what would be the result if the inside pole faces of a 1,040-volt alternation were to be planed off $\frac{1}{8}$ inch? (*b*) Why does not the primary coil of a transformer short-circuit the mains? (*c*) What is the carrying capacity of a No. 00 B. & S. cotton-covered copper wire?

W. K., Tacoma, Washington.

ANS.—(*a*) The output of the machine would be considerably diminished. (*b*) An incandescent lamp is not said to short-circuit electric mains; no more does the primary coil of a transformer which is of high ohmic resistance, and also possesses a large artificial resistance due to self-induction, or counter-electromotive force, generated by the magnetism from the primary current. When the secondary circuit is open, this counter-electromotive force nearly equals the applied, or impressed electromotive force, at the primary terminals, so that the real acting

electromotive is very small and the current in the primary coil is extremely small. (*c*) About 120 amperes.

***

(35) (*a*) Please state how a two-wire system can be changed into a three-wire system, and what size wire the positive and negative must be as compared with the neutral. (*b*) Please explain how to find the size of cut-out to use when the number of lamps, sizes of conductors, etc. are known. (*c*) How many cells, connected in series, will be required to run a 110-volt lamp? (*d*) How many volts are required to kill the average man? (*e*) Is it cheaper to buy current for a building using 500 lights, or to generate the current in the building and pay a man $3.00 a day to run it? (*f*) Please give directions for making a small battery of two cells. J. W. H., Boston, Mass.

ANS.—(*a*) To change a two-wire system over to a three-wire necessitates running a third wire and altering the branch-circuits to correspond. The neutral wire is generally one-half the size of the negative, or the positive A three-wire system can be changed over to a two-wire system by connecting the two outside mains to one terminal of a dynamo and the neutral to the other terminal of the machine. (*b*) If the number of lamps is known, the current can be immediately calculated. The cut-out chosen should be amply large to carry this current, provided the design is correctly made. For example, suppose that 50 branch-circuits, of No. 14 B. & S. G. wire, extend from a 50-ampere cut-out to 50 lamps, which require in all 50 amperes. As the installation now stands, is it a proper one? No! For, suppose a short circuit occurs between two of the No. 14 wires, a large quantity of current begins to flow which the fuse is able to carry at least for a few seconds and which melts the wire and probably grounds the system. Or, suppose a short circuit occurs in one of the lamp sockets; the abnormal current flows only a few moments, but plenty long enough to melt the insulation and probably cause a short circuit and also a ground. A short circuit or ground can hardly occur without an arc, and *an electric arc is fire.* (*c*) See answer to question 518, HOME STUDY MAGAZINE for December, 1897. (*d*) Electricity kills by contracting the muscles and stopping the action of the heart; consequently it is not volts, but *amperes*, that kill. The amount of current that passes through a body depends on the volts applied, the manner of application, and the internal structure of the body. With good electrical contact and a continued application, two hundred volts direct current may kill some persons. Alternating currents apparently keep more to the surface of a body, and, consequently, higher voltages can be received with less effect, the effect decreasing as the number of alternations per second is increased. A lineman in Philadelphia recently received over one thousand volts, alternating current, for a considerable length of time. His escape from being killed is due to the fact that the current passed through his body on the opposite side to his heart, and that the alternating character of the current tended to keep the electricity near the surface of his body. By greatly increasing the number of alternations, Tesla has allowed many thousands of volts to be applied to his body without ill effect. (*e*) You will have to consult the prices of the local lighting company, and compare figures with the amount that it will cost you to generate the current. (*f*) See answers to questions 290 and 295 HOME STUDY MAGAZINE for August, 1897.

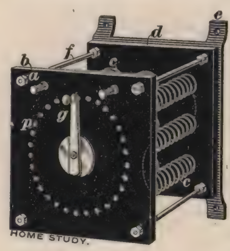
***

(36) Is there any way in which I can determine the absorptive quality of brick or stone? F. H. G., Buffalo, N. Y.

ANS.—See answer to question 451, HOME STUDY MAGAZINE for November, 1897.

(37) Kindly inform me how to make a field-rheostat, and how much resistance is necessary for a 30-horsepower compound-wound dynamo, for incandescent lighting at 110 volts. D. H. P., New York, N. Y.

ANS.—Procure two slate slabs, about 10 inches square and ⅞ inch thick, and prepare them for mounting on the wrought-iron base *e*, by the four ½-inch corner bolts *f*. With a common twist-drill, bore the four corner holes *a* in each slab and the wrought-iron base. Then drill nine holes nearly but not quite through the slabs. Into these holes, cement hooks, to be used to support the resistance-coils. The contacts *p* should be of brass, but if this is not convenient, stove-bolts may be used. For their reception make thirty or forty holes—the more the better. Another larger hole must now be drilled at the center for the center bolt. Two binding posts at the top of the front slate are also to be provided for. The finger *g* should be made of spring brass and wide enough to cover two contacts. About 50 feet of No. 14 B. & S. galvanized iron wire is then laid out on the floor, and, to this, wire taps of No. 16 B. & S. insulated copper wire about 14 inches long are soldered at regular intervals. There should be as many taps as contacts, one tap being soldered at each end also. The iron wire is then coiled on mandrels and afterwards slipped off and hung on the hooks previously prepared. The taps are then connected in regular order to the farther ends of the contact-bolts by a nut. Each contact-bolt will then have a nut to fasten it to the slab and another immediately following to hold the wire. A bent piece of brass is screwed under the contact, on which the lever is now shown to be resting, so that the lever can move no farther to the right. One binding post is now wired to the last contact—last, when the lever is moved around in the direction of *p*; the other binding post is connected with the center plate *f*. The present position of the finger shows all the resistance cut in. If the box is likely to be subjected to vibrations, asbestos rolls may be inserted in the coils. A cover is now put around the top, two sides, and bottom. This casing should be provided with openings for the free access of air for cooling the coils.



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(38) (*a*) When an alternating current of electricity is passed through a transformer, is the current induced in the secondary "alternating" or "continuous"? (*b*) If alternating, is there any appliance on the market that will change an alternating current into a direct current? D. L., New York, N. Y.

ANS.—(*a*) Alternating. (*b*) A rotary transformer.

***

(39) On page 84, December number of HOME STUDY FOR THE BUILDING TRADES, in the article entitled Constructive Details, it is stated that a safety factor of 6 was used in the suspension rods of the musicians' gallery, so that the value accredited to each rod would be 13,500 pounds ÷ 6 = 2,250 pounds. I cannot see why you divided by 6, and should think that in order to increase the strength of each rod six-fold you would multiply 13,500 pounds by 6, making the ultimate capacity equal 81,000 pounds. H. C. L., Starwick, N. J.

ANS.—As 13,500 pounds was the calculated *ultimate strength* of each suspension rod, it was necessary to *divide* that value by 6 (the safety factor) in order to get the load which would be safely sustained by each rod. In other words, a value of 2,250 pounds

being assigned to each rod, they would each be able to carrying *six times* this amount before rupture would take place.

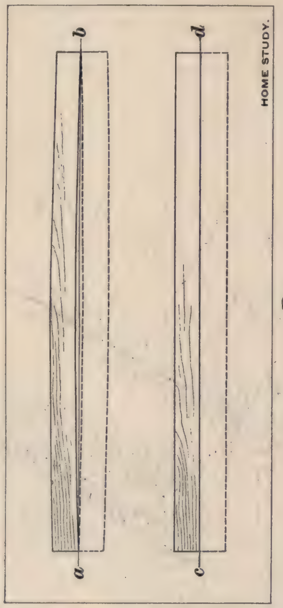
***

(40) (*a*) Send rule, if there is any, for jointing long timber. (*b*) How can I test a straight line on a board? (*c*) Can you give me the address of some one who carries a line of paper letters?

C. R. P., Baltimore, Md.

ANS.—(*a*) A chalk-line is generally employed for the purpose. By stretching the chalk-line tightly between the nails set to the desired line and snapping it, as shown in diagram *A*, the line so made will be as nearly true as it is possible to draw it. The line may be tested with a long straight-edge, if so desired. (*b*) To test a straight line on a board we would suggest the method shown in diagram *B*. It will be noticed at *a b* that the testing-rule employed was not a straight-edge, or, in other words, was not true. After fixing the ends to two points *a*, *b*, draw a line along the edge of the rule, then reverse the rule to take the position indicated by dotted lines, keeping the ends of the rule on the points *a* and *b*. Draw a line along this edge of the rule; then, if a line be drawn bisecting the space between these lines it will be a straight line. At *c d* is shown a straight line drawn with a true straight-edge. (*c*) Address A. Wiggers, 215 East 59th St., New York City.

A



B

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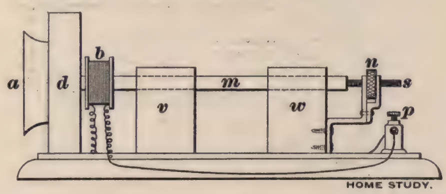
(41) I have put up a telephone line, about 200 feet long, which works well without a battery. The instrument used for a transmitter and a receiver is shown in the sketch, and consists of a bar magnet *m* mounted on the wooden blocks *v* and *w*, adjustable endwise by the nut and screw *n* and *s*. On one end is fixed the bobbin *b*. The ends of the coil are brought to two binding posts *p*. The diaphragm is contained in the box *d*, immediately in front of which is the mouthpiece *a*. The diaphragm is about one thirty-second of an inch from the end of the magnet *m*. Please explain how this works without a battery.

C. K. T., Vicksburg, Miss.

ANS.—Perhaps you have unconsciously placed a battery in circuit. If not, the instrument is evidently well made and the line resistance low. The action of the instrument used as a transmitter is as follows: The voice striking the diaphragm enclosed in the box *d* causes it to vibrate. The diaphragm, being a conductor of magnetism, causes fluctuations in the magnetic field at the end and all through the magnet *m*. These fluctuations of magnetism in the core of the bobbin *b* induce an alternating, or fluctuating, current in the coil *b*. This alternating current passes over the line to a similar instrument used as a receiver. There the action is reversed. The alternating current in the bobbin affects the magnetism, which in turn moves the diaphragm, so that it gives forth the sound.



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(42) Can you tell me of a good book on practical blacksmithing? A. R., Richmond, Va.

ANS.—Practical Blacksmithing, in four volumes, by M. T. Richardson. This book can be obtained from The Technical Supply Co., of Scranton, Pa.

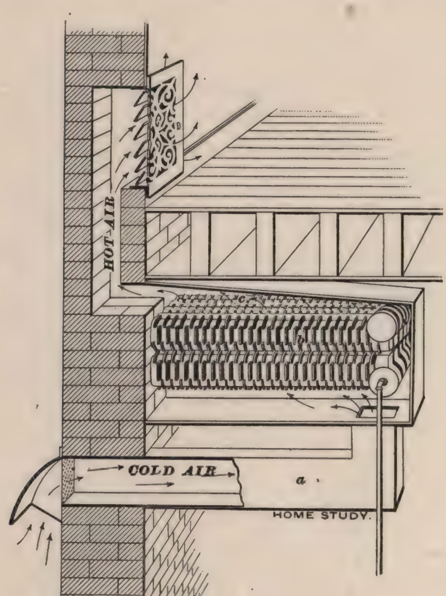
***

(43) I am a young carpenter of about four years' experience in our village. My father intends to build a new house next spring and asked me to draw the plans for it during the evenings of this coming winter. I have got along pretty well with my drawing course in The International Correspondence Schools, and I think I will be able to make a nice set of plans. I would like to ask you for some information, however, on "indirect radiation." What is meant by indirect radiation, and how does it work? Kindly give me a sketch and explain how I should show it in the plans, if need be.

X. Y., Seymour, Conn.

ANS.—"Indirect radiation" is a term used to signify that the rooms of the building are warmed by radiators which are located elsewhere than in the rooms so warmed. When steam or hot-water radiators are used to heat a building, they are known as "direct radiators" if they are located within the

rooms, because they thus heat the rooms in the most direct manner. With the indirect method, however, the heat is conveyed from the radiator to the room by means of a current of air. Indirect radiators are usually hung from the cellar-ceiling, and are enclosed in a sheet-metal casing (usually No. 20 galvanized sheet iron), or a tin-lined wooden casing, which is provided with a chamber above and one below the radiator, as shown in the figure. Cold air from the outer atmosphere enters the lower chamber through a No. 20 galvanized sheet-iron pipe *a*, called the cold-air duct. It then passes up between the sections of the radiator *b* and is heated before it enters the upper



chamber *c*. Another galvanized-iron or bright tin pipe, called the hot-air pipe, or duct, joins this chamber to a register in the floor or side wall of the room to be heated, and thus permits the warm air to rise and flow into the room, as shown by the arrows. If you decide to show the location of the indirect radiators on your plans, you can easily do so by simply drawing their outlines on the cellar plan. You should also locate the boiler and chimney on the same plan. This will enable the steam-fitter to give you an accurate bid on the work.

***

(44) I consider the Answers to Inquiries in your magazine most interesting. (*a*) Kindly inform me how Spanish tiles are fastened on a roof. (*b*) How are gutters constructed? (*c*) How are *valleys* constructed? (*d*) How are *hips* constructed? (*e*) How are connections made with gable walls? (*f*) Will snow blow through a properly constructed tile roof? (*g*) How does terra-cotta of special design compare with stone in cost and durability for outside facings? (*h*) How is the stone hectograph made?

J. W. R., Hammond, Ind.

ANS.—(*a*) Spanish roofing-tiles are made in two styles. One is the plain ∽ shape with one roll concave and one convex, and having nail-holes punched about 1 inch from the top. The other has the same shape, and is known as interlocking, which term is applied because about 3 inches below the top of the tile and below the nail-holes is a neck, or fillet, over which the lip of the tile above laps. Both of these tiles are manufactured by some companies with a lug or rib cast on the upper under edge by which to hang the tile to the lath. The tiles should be secured to the roof with two copper nails, as at *a*, in Fig. 1. To prepare the roof for the tiles, the following is the usual

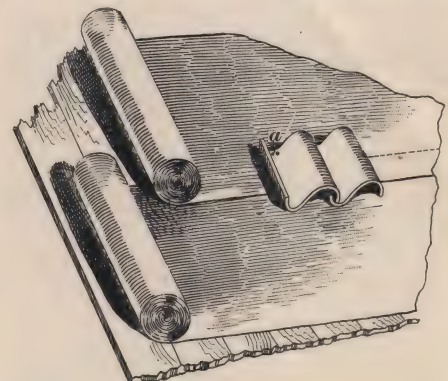


FIG. 1.

custom: Sheathe the roof diagonally with roofing-boards well nailed at each bearing. Cover the entire roof with two-ply felt or roofing-paper, as in Fig. 1. Securely nail the tilting-fillets to the roof-boards, as at *f*, Figs. 2, 3, and 5. (*b*) The gutter at the cornice should have a galvanized-iron frame, or cradle, or, if of cast iron, the frames should be cast the shape of the gutter and set at not more than 30-inch centers and tied with a band, or rod, on the outside. The end of the frames

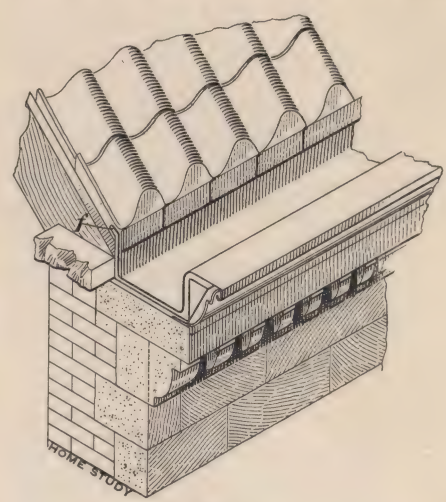


FIG. 2.

should extend into the wall and form an anchor. The cradle should then be filled in with cement or concrete, and covered with roofing-felt. The crown molding of 18-ounce copper should next be put in place, and the gutter proper, of the same weight metal, in lengths of 6 or 8 feet and joined by ⅝-inch lock-seams, thoroughly soldered and sweated together, should be placed in the cradle. The inner

edge of the gutter should be turned up against the plate to the top of the fillet, the outer edge connecting with the crown molding in a lock-seam. The lining or flashing under the tile should be nailed to the

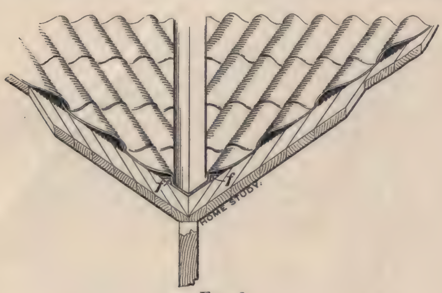


FIG. 3.

tilting-fillet with copper nails, turned down over the fillet and connected with the inner side of the gutter by a double-locked seam. (See Fig. 2.) These outer and inner seams of the gutter should not be soldered, as the expansion and contraction must be provided for. It would be well, also, if the gutter is a very long one, to pitch it both ways and use a 2-inch or 2½-inch roll lock-seam at the center, unsoldered, as an expansion-joint. (*c*) The valleys should be constructed of from 16 to 18 oz. copper in not more than 6-foot lengths, laid with a lock-seam and secured to the roof-boards by cleats of copper, soldered or sweated on the back of each length, and fastened to the roof with copper nails or with copper screws. The sides of the valley should be turned up 1 inch against the tilting-fillet, bent over its top, and nailed securely along its length. The general appearance under this treatment will be as in Fig. 3. (*d*) The hips do not require any flashings. Nail a 2″ x 5″ strip on the angle of the roof, the 5-inch side standing up, bring the tile against it, and cover with a hip-roll, as in Fig. 4. (*e*) The connection with the gable-walls should be made by first nailing the copper to the tilting-fillet and turning it *down* over the same to the

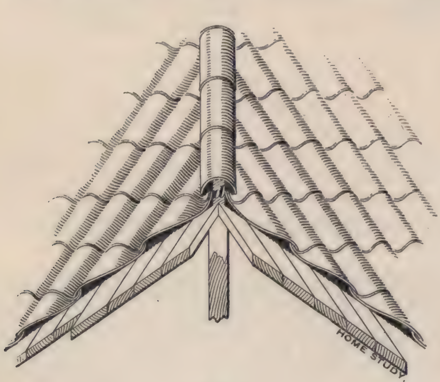


FIG. 4.

roof and then *up* against the wall at least 7 inches. From the under side of the coping turn down a 6-pound lead apron-flashing, overlapping the copper 3 inches. The vertical part of the roof-flashing should be secured to the wall by cleats not more than 18 or 20 inches apart. The lead apron will be held in place by lead plugs 1″ x ½″ at 12-inch centers. (*f*) Snow will not blow through a properly constructed tile roof for the following reasons: The roof being boarded and covered with roofing-felt, effectually stops the passage of air, and the open space under the tiles forms an air cushion, or pocket, which prevents any drift. On laths this would not be the case, as there would be no backing. A boarded and felted roof, if exposed to the air on the under side, will last as long as a lath roof if the boards are not too closely laid and if the tiles are uncemented. The tiles on the eaves, gutters, valleys, hips, and ridges should be laid in elastic cement composed of linseed-oil, whiting and resin and applied while hot. (*g*) Terra-cotta of special designs in small quantities is always more expensive than stone. If, however, the whole front is to be of terra-cotta, it will be 18 or 20 per cent. cheaper than limestone, and about 30 per cent. cheaper than brownstone or bluestone, in a building of ordinary width and 5 or 6 stories high. Terra-cotta is just as durable as stone, and possesses the advantage of being absolutely fireproof. (*h*) A hectograph consists of a gelatin pad to which impressions of

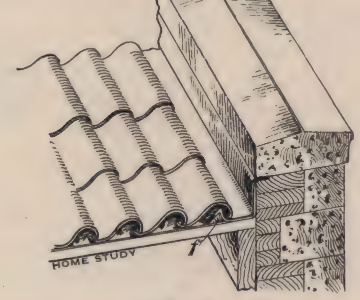


FIG. 5.

drawings made in aniline inks are transferred, and from which a large number of prints can be taken. See the answer to Question 430, in the November, 1897, number of HOME STUDY MAGAZINE. Hectographing upon stone is a similar process, in which a polished stone slab is used in lieu of a gelatin pad, and to which impressions are transferred from drawings made with lithographic and other patented inks. The formulæ for making these inks are trade secrets and unknown to us.

***

(45) Will you kindly inform me how a narrow church-spire can be prevented from swaying in the wind? The rafters of the spire seem to be as well braced as possible, but, nevertheless, the spire bends like a mast in a gale of wind.

BUILDER, Washington, D. C.

ANS.—The swaying of a spire or steeple may be prevented by suspending a heavy beam or weight from the apex of the spire. The lower the weight below the spire the greater will be the stability of the structure. The Japanese resort to this mode of treating the roofs of their towers as a precaution against earthquakes, allowing the beam to swing free so as to act as a pendulum, bringing the structure back to its perpendicular position after deflection by wind or earthquake tremor. Whether a weight so swinging actually tends to draw a deflected spire back to its perpendicularity or not is doubtful; but by attaching a weight to the apex of a spire and suspending it some distance below the spire-roof, the center of gravity will be lowered in proportion to the distance the weight may hang below the natural center of gravity of the spire.

(46) I am thinking of using a rope for transmitting power. The driver-pulley is 28″ in diameter, the driven 36″. The shafts are 10 feet center to center, and I intend to use a tightener on the slack side of the rope. Those claiming to have had experience say that this arrangement will not work, but that the pulleys should be at least 100 feet apart. Is this so? J. R., Kanopolis, Kansas.

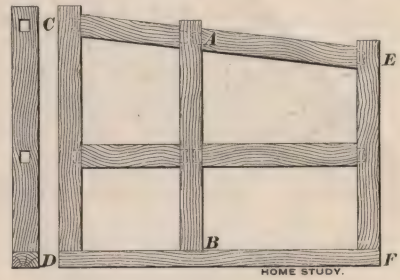
ANS.—You can, of course, use a rope drive in the way you propose; but, leaving out of consideration all question of space, it is much preferable to have the pulleys farther apart, say 30 feet at least. The general practice is to place them much farther apart than this, sometimes twice as far, depending on circumstances. This is done with a view to the increased weight of rope producing the necessary adhesion on the pulley, the sag of the rope at the same time increasing the arc of contact. (The top side, of course, is made the driving side.) The ropes should not rest on the bottom but on the sides of the grooves, the wedging action thus set up supplying the resistance to slipping that is secured in flat-belt drivers by means of great initial tension. The sides of the groove may include an angle of 45°, this being found to give good results. In a long drive, the weight of rope secures the necessary adhesion without any great initial tightening of the rope. This gives a greater life to the rope than would happen in your case. The tension pulley or tightener you propose to use has an injurious effect on the ropes, inducing a reverse bending, although this will perhaps not be so marked as in a longer drive, with, consequently, a greater sag.

***

(47) (*a*) Please tell me how to level across a stream 1,500 feet wide, if the water-level is not to be depended upon. (*b*) Where should I establish a bench-mark in a city? (*c*) Where in the country? (*d*) How should I establish it in a swamp? (*e*) In framing posts how do I find the distance AB in the accompanying diagram? (*f*) How do I find where to cut mortise at A to carry roof-thighs CA and AE? (*g*) How do I find length of CA and AE?

NEW YORK READER.

ANS.—(*a*) Level across with an engineer's level having a high-power telescope, preferably with a *precise level*, such as is used in the United States Coast Survey. In order that the result may be accurate, several observations should be taken. If all observations are taken from the same side of the river, a correction for curvature and refraction should be made. For a distance of 1,500 feet, the correction for the earth's curvature and refraction under ordinary atmospheric conditions will be .046 of a foot. This correction is to be deducted from the reading of the leveling-rod. If observations are taken from both sides of the river, however, the error due to curvature and refraction may be eliminated by taking a mean of the results obtained by the observations from opposite directions. (*b*) and (*c*) On any permanent and well-defined object, such as the water-table of a public building, or upon a stone monument planted in the ground. The water-table of a stone or brick dwelling-house will do, but the more permanent and sharply defined the object is, the better. (*d*) Cut into the root of a large tree in such a manner as to make a projection shaped somewhat like an inverted letter V, the top coming to a well-defined point, and drive a tack in the top on which to hold the rod. Blaze the top of the tree so it can be found easily, and, in order to easily distinguish it from other blazed trees, mark the letters B. M. on the blaze with red chalk. If the bench-mark is to be used frequently, it is a good plan to also mark its elevation on the blaze. Keep an accurate record of the position and elevation of each bench-mark, with a sufficient description to positively identify it. For any system of levels, the elevation of the bench-mark from which the levels are started must be either assumed or obtained from some other system of levels. It is a common practice to assume the



elevation of this primary bench-mark at such a distance above base that the elevation of every point in the system will be above base, thus avoiding negative elevations; an elevation of 100 feet is often assumed for the primary bench-mark. For locations near tide-water it is becoming a quite general practice to base the elevations of bench-marks upon the elevation of mean tide, and this practice is to be commended.

(*e*) Distance $AB = \dfrac{BF \times CD + DF \times EF}{DF}$

$$(g)\quad CA = \frac{DB}{DF}\sqrt{(DF)^2 + (CD - EF)^2}.$$

$$AE = \frac{BF}{DF}\sqrt{(DF)^2 + (CD - EF)^2}.$$

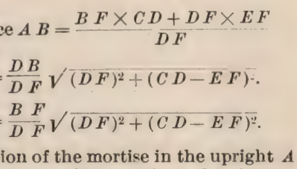
(*f*) The position of the mortise in the upright AB can best be found by marking off from the pieces CA and AE.

***

(48) Referring to the answer to question 241 which appeared in the July number of HOME STUDY MAGAZINE, how was the constant angle 74° 46′ 15″ obtained?

J. L. McL., San Marcos, Texas.

ANS.—Let y be the circular measure of the angle A; then, bp = arc acb = (circumference − arc axb) $= 2\,o\,b(\pi - y)$. And $\tan y = \dfrac{bp}{ob} = \dfrac{2\,ob(\pi - y)}{ob} = 2(\pi - y)$. This equation $\tan y = 2(\pi - y)$ determines the angle y, or A; this equation can only be solved by trial. As the angle y increases from o to $\frac{\pi}{2}$, $\tan y$ increases from o to infinity; and $2(\pi - y)$ decreases from 2π to π, or from 6.28318 to 3.14159. Hence, $\tan y$ must lie between 6.28318 and 3.14159. From a table of natural tangents, tan 74° 46′ = 3.67217; from a table of circular measures of angles, circular measure of 2(180° − 74° 46′) = circular measure of 2(105° 14′) = 3.67334. Since tan 74° 46′ is less than the circular measure of 2(180° − 74° 46′), this angle is too small. A second trial gives tan 74° 46′ 15″ = 3.67322, and circular measure of 2(180° − 74° 46′ 15″) = 3.67320. Therefore, A = 74° 46′ 15″.



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